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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	6338.157
First Inventor	Chris Thornberry
Title	A Method and System for Quick Squar
Express Mail Label No.	Electronically Transmitted

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☐ **Fee Transmittal Form** (e.g., PTO/SB/17)
2. ☑ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 36]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 9]
5. **Oath or Declaration** [*Total Sheets*]
   a. ☑ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
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      ii. ☐ Paper
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ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (Should be specifically itemized)
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ Other:

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.:

Prior application information: *Examiner* *Art Unit:*

19. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 30589 *OR* ☑ Correspondence address below

Name	Dunlap Codding, P.C.				
Address	P.O. Box 16370				
City	Oklahoma City	State	Oklahoma	Zip Code	73113
Country	USA	Telephone	405-607-8600	Email	dsorocco@dunlapcodding.com

Signature		Date	03/19/2012
Name (Print/Type)	Douglas J. Sorocco	Registration No. (Attorney/Agent)	43,145

This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
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Electronically Transmitted: March 19, 2012 **Utility**

A Method and System for Quick Square Roof Reporting

Cross-Reference to Related Applications

[0001] Not Applicable.

Background

[0002] Residential and/or commercial property owners approaching a major roofing project may be unsure of the amount of material needed and/or the next step in completing the project. Generally, such owners contact one or more contractors for a site visit. Each contractor must physically be present at the site of the structure in order to make a determination on material needs and/or time. The time and energy for providing such an estimate becomes laborious and may be affected by contractor timing, weather, contractor education, and the like. Estimates may be varied even between contractors in determination of estimated square footage causing variance in supply ordering as well. Additionally, measuring an actual roof may be costly and potentially hazardous – especially with steeply pitched roofs. Completion of a proposed roofing project may depend on ease in obtaining a simplified roofing estimate and/or obtaining reputable contractors for the roofing project.

[0003] Images are currently being used to measure objects and structures within the images, as well as to be able to determine geographic locations of points within the image when preparing estimates for a variety of construction projects, such as roadwork, concrete work, and roofing. Estimating construction projects using software may increase speed at which an estimate can be prepared, and may reduce labor and fuel costs associated with on-site visits.

Brief Description of the Several Views of the Drawings

[0004] Like reference numerals in the figures represent and refer to the same or similar element or function. Implementations of the disclosure may be better understood when consideration is given to the following detailed description thereof. Such description makes reference to the annexed pictorial illustrations, schematics, graphs, drawings, and appendices. In the drawings:

[0005] FIG. 1 is a schematic diagram of an embodiment of a roof estimator reporting system according to the instant disclosure.

[0006] FIG. 2 is a block diagram of an embodiment of one or more memory according to the instant disclosure.

[0007] FIG. 3 is an exemplary embodiment of a program logic according to the instant disclosure.

[0008] FIG. 4 is another exemplary embodiment of a program logic according to the instant disclosure.

[0009] FIG. 5 is yet another exemplary embodiment of a program logic according to the instant disclosure.

[0010] FIG. 6 is a further exemplary embodiment of a program logic according to the instant disclosure.

[0011] FIG. 7 is an exemplary slope factor chart for determining pitch factors according to the instant disclosure.

[0012] FIG. 8 is an exemplary embodiment of a roofing report presentation page according to the instant disclosure.

Detailed Description of Inventive Concept

[0013] Before explaining at least one embodiment of the inventive concept disclosed herein in detail, it is to be understood that the inventive concept is not limited in its application to the details of construction and the arrangement of the components or steps or methodologies set forth in the following description or illustrated in the drawings. The inventive concept disclosed herein is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for the purpose of description and should not be regarded as limiting in any way.

[0014] In the following detailed description of embodiments of the inventive concept, numerous specific details are set forth in order to provide a more thorough understanding of the inventive concept. It will be apparent to one of ordinary skill in the art, however, that the inventive concept within the disclosure may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid unnecessarily complicating the instant disclosure.

[0015] Referring now to the drawings, and in particular to FIG. 1, shown therein and designated by a reference numeral 100 is an exemplary computer system 100 constructed in accordance with the present disclosure. The system 100 can be a system or systems that are able to embody and/or execute the logic of the processes described herein. The logic embodied in the form of software instructions, or firmware may be executed on any appropriate hardware which may be a dedicated system or systems.

[0016] As used herein, the terms "network-based", "cloud-based" and any variations thereof, are intended to include the provision of configurable computational resources on demand via interfacing with a computer and/or computer network, with software and/or data at least partially located on the computer and/or computer network, by pooling processing power of two or more networked processors.

[0017] As used herein, the terms "comprises", "comprising", "includes", "including", "has", "having", or any other variation thereof, are intended to be non-exclusive inclusions. For example, a process, method, article, or apparatus that comprises a set of elements is not limited to only those elements but may include other elements not expressly listed or even inherent to such process, method, article, or apparatus.

[0018] As used in the instant disclosure, the terms "provide", "providing", and variations thereof comprise displaying or providing for display a webpage (e.g., roofing webpage) to one or more user terminals interfacing with a computer and/or computer network(s) and/or allowing the one or more user terminal(s) to participate, such as by interacting with one or more mechanisms on a webpage (e.g., roofing webpage) by sending and/or receiving signals (e.g., digital, optical, and/or the like) via a computer network interface (e.g., Ethernet port, TCP/IP port, optical port, cable modem, and combinations thereof). A user may be provided with a web page in a web browser, or in a software application, for example.

[0019] As used herein, the term "roof request", "roofing request", "roofing order", and any variations thereof may comprise a feature of the graphical user interface or a feature of a software application, allowing a user to indicate to a host system that the

user wishes to place an order, such as by interfacing with the host system over a computer network and exchanging signals (e.g., digital, optical, and/or the like), with the host system using a network protocol, for example. Such mechanism may be implemented with computer executable code executed by one or more processors, for example, with a button, a hyperlink, an icon, a clickable symbol, and/or combinations thereof, that may be activated by a user terminal interfacing with the at least one processor over a computer network, for example.

[0020] Further, unless expressly stated to the contrary, "or" refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by anyone of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0021] In addition, the use of the "a" or "an" are employed to describe elements and components of the embodiments herein. This is done merely for convenience and to give a general sense of the inventive concept. This description should be read to include one or more, and the singular also includes the plural unless it is obvious that it is meant otherwise.

[0022] Finally, as used herein any reference to "one embodiment" or "an embodiment" means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearance of the phrase "in one embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

[0023] Referring now to FIG. 1, shown therein is an exemplary embodiment of a roof estimator reporting system 100 according to the instant disclosure. The system

100 comprises two or more host systems 102 and 126 interfacing and/or communicating with one or more user terminals 104 via a network 106.

[0024] The one or more user terminals 104 may be implemented as a personal computer, a smart phone, network-capable TV set, TV set-top box, a tablet, an e-book reader, a laptop computer, a desktop computer, a network-capable handheld device, a video game console, a server, a digital video recorder, a DVD-player, a Blu-Ray player and combinations thereof, for example. In an exemplary embodiment, the user terminal 104 may comprise an input device 122, an output device 124, a processor (not shown) capable of interfacing with the network 106, processor executable code (not shown), and a web browser capable of accessing a website and/or communicating information and/or data over a network, such as the network 106. As will be understood by persons of ordinary skill in the art, the one or more user terminals 104 may comprise one or more non-transient memories comprising processor executable code and/or software applications, for example.

[0025] The input device 122 may be capable of receiving information input from a user and/or other processor(s), and transmitting such information to the user terminal 104 and/or to the host system 102. The input device 122 may be implemented as a keyboard, a touchscreen, a mouse, a trackball, a microphone, a fingerprint reader, an infrared port, a slide-out keyboard, a flip-out keyboard, a cell phone, a PDA, a video game controller, a remote control, a fax machine, a network interface, and combinations thereof, for example.

[0026] The output device 124 may output information in a form perceivable by a user and/or other processor(s). For example, the output device 124 may be a server, a

computer monitor, a screen, a touchscreen, a speaker, a website, a TV set, a smart phone, a PDA, a cell phone, a fax machine, a printer, a laptop computer, and combinations thereof. It is to be understood that in some exemplary embodiments, the input device 122 and the output device 124 may be implemented as a single device, such as, for example, a touchscreen or a tablet. It is to be further understood that as used herein the term user is not limited to a human being, and may comprise a computer, a server, a website, a processor, a network interface, a human, a user terminal, a virtual computer, and combinations thereof, for example.

[0027] The system 100 may include one or more host systems. For example, FIG. 1 illustrates system 100 having two host systems 102 and 126. The host systems 102 and 126 may be partially or completely network-based or cloud based, and not necessarily located in a single physical location. Each of the host systems 102 and 126 may further be capable of interfacing and/or communicating with the one or more user terminals 104 via the network 106, such as by exchanging signals (e.g., digital, optical, and/or the like) via one or more ports (e.g., physical or virtual) using a network protocol, for example. Additionally, each host system 102 and 126 may be capable of interfacing and/or communicating with other host systems directly and/or via the network 106, such as by exchanging signals (e.g., digital, optical, and/or the like) via one or more ports.

[0028] In some embodiments, host systems 102 and 126 may be independently controlled by separate entities. Host system 102 may be controlled by a first company and host system 126 may be controlled by a second company distinct from the first company. For example, host system 102 may be controlled by a roofing material

supplier and host system 126 may be controlled by a roofing report company. The roofing material supplier may be a separate entity from the roofing report company.

[0029] The host system 102 may be referred to hereinafter as the "first host system" and the host system 126 may be referred to hereinafter as the "second host system". The first host system 102 may comprise one or more processors 108 working together, or independently to, execute processor executable code, one or more memories 110 capable of storing processor executable code, one or more input devices 112, and one or more output devices 114. Each element of the first host system 102 may be partially or completely network-based or cloud-based, and not necessarily located in a single physical location.

[0030] The one or more processors 108 may be implemented as a single or plurality of processors 108 working together, or independently to execute the logic as described herein. Exemplary embodiments of the one or more processors 108 include a digital signal processor (DSP), a central processing unit (CPU), a field programmable gate array (FPGA), a microprocessor, a multi-core processor, and/or combinations thereof. The one or more processors 108 may be capable of communicating with the one or more memories 110 via a path (e.g., data bus). The one or more processors 108 may be capable of communicating with the input devices 112 and the output devices 114.

[0031] The one or more processors 108 may be further capable of interfacing and/or communicating with the one or more user terminals 104 via the network 106. For example, the one or more processors 108 may be capable of communicating via the network 106 by exchanging signals (e.g., digital, optical, and/or the like) via one or more

physical or virtual ports using a network protocol. It is to be understood that in certain embodiments using more than one processor 108, the one or more processors 108 may be located remotely from one another, located in the same location, or comprising a unitary multi-core processor (not shown). The one or more processors 108 may be capable of reading and/or executing processor executable code and/or of creating, manipulating, altering, and/or storing computer data structures into one or more memories 110.

[0032] The one or more memories 110 may be capable of storing processor executable code. Additionally, the one or more memories 110 may be implemented as a conventional non-transient memory 110, such as, for example, random access memory (RAM), a CD-ROM, a hard drive, a solid state drive, a flash drive, a memory card, a DVD-ROM, a floppy disk, an optical drive, and/or combinations thereof. It is to be understood that while one or more memories 110 may be located in the same physical location as the first host system 102, the one or more memories 110 may be located remotely from the first host system 102, and may communicate with the one or more processor 108 via the network 106. Additionally, when more than one memory 110 is used, a first memory 110 may be located in the same physical location as the first host system 102, and additional memories 110 may be located in a remote physical location from the first host system 102. The physical location(s) of the one or more memories 110 may be varied. Additionally, one or more memories 110 may be implemented as a "cloud memory" (i.e., one or more memory 110 may be partially or completely based on or accessed using the network 106).

[0033] The one or more input devices 112 may transmit data to the processors 108, and may be implemented as a keyboard, a mouse, a touchscreen, a camera, a cellular phone, a tablet, a smart phone, a PDA, a microphone, a network adapter, and/or combinations thereof. The input devices 112 may be located in the same physical location as the first host system 102, or may be remotely located and/or partially or completely network-based.

[0034] The one or more output devices 114 may transmit information from the processor 108 to a user, such that the information may be perceived by the user. For example, the output devices 114 may be implemented as a server, a computer monitor, a cell phone, a tablet, a speaker, a website, a PDA, a fax, a printer, a projector, a laptop monitor, and/or combinations thereof. The output device 114 may be physically co-located with the first host system 102, or may be located remotely from the first host system 102, and may be partially or completely network based (e.g., website). As used herein, the term "user" is not limited to a human, and may comprise a human, a computer, a host system, a smart phone, a tablet, and/or combinations thereof, for example.

[0035] The first host system 102 may directly communicate with the second host system 126 and/or communicate via network 106. Generally, the first host system 102 may include one or more processors 108 capable of executing a first set of processor executable code and the second host system 126 may include one or more processors 128 capable of executing a second set of processor executable code.

[0036] The second host system 126 may further comprise one or more memories 130 capable of storing processor executable code, one or more input devices 132, and

one or more output devices 134. Each element of the second host system 126 may be partially or completely network-based or cloud based, and not necessarily located in a single physical location.

[0037] The one or more processors 128 may be implemented as a single or a plurality of processors 128 working together to execute the logic described herein. Exemplary embodiments of the one or more processors 128 include a digital signal processor (DSP), a central processing unit (CPU), a field programmable gate array (FPGA), a microprocessor, a multi-core processor, and/or combinations thereof. The one or more processors 128 may be capable of communicating with the one or more memories 130 via a path (e.g., data bus). The one or more processors 128 may be capable of communicating with the input devices 132 and the output devices 134.

[0038] The one or more processors 128 may be further capable of interfacing and/or communicating with the one or more user terminals 104 via the network 106. For example, the one or more processors 128 may be capable of communicating via the network 106 by exchanging signals (e.g., digital, optical, and/or the like) via one or more physical or virtual ports using a network protocol. It is to be understood that in certain embodiments using more than one processor 128, the one or more processors 128 may be located remotely from one another, located in the same location, or comprising a unitary multi-core processor (not shown). The one or more processors 128 may be capable of reading and/or executing processor executable code and/or of creating, manipulating, altering, and/or storing computer data structures into one or more memories 130.

[0039] The one or more memories 130 may be capable of storing processor executable code. Additionally, the one or more memories 130 may be implemented as a conventional non-transient memory 130, such as, for example, random access memory (RAM), a CD-ROM, a hard drive, a solid state drive, a flash drive, a memory card, a DVD-ROM, a floppy disk, an optical drive, and/or combinations thereof. It is to be understood that while one or more memories 130 may be located in the same physical location as the second host system 126, the one or more memories 130 may be located remotely from the second host system 126, and may communicate with the one or more processor 128 via the network 106. Additionally, when more than one memory 130 is used, a first memory 130 may be located in the same physical location as the second host system 126, and additional memories 130 may be located in a remote physical location from the second host system 126. The physical location(s) of the one or more memories 130 may be varied. Additionally, one or more memories 130 may be implemented as a "cloud memory" (i.e., one or more memory 130 may be partially or completely based on or accessed using the network 106).

[0040] The input devices 132 may transmit data to the processors 128, and may be implemented as a keyboard, a mouse, a touchscreen, a camera, a cellular phone, a tablet, a smart phone, a PDA, a microphone, a network adapter, and/or combinations thereof. The input devices 132 may be located in the same physical location as the second host system 126, or may be remotely located and/or partially or completely network-based.

[0041] The output devices 134 may transmit information from the processors 128 to a user, such that the information may be perceived by the user. For example, the

output devices 134 may be implemented as a server, a computer monitor, a cell phone, a tablet, a speaker, a website, a PDA, a fax, a printer, a projector, a laptop monitor, and/or combinations thereof. The output devices 134 may be physically co-located with the second host system 126, or may be located remotely from the second host system 126, and may be partially or completely network based (e.g., website).

[0042] The network 106 may permit bi-directional communication of information and/or data between the first host system 102, the second host system 126 and/or user terminals 104. The network 106 may interface with the first host system 102, the second host system 126, and the user terminals 104 in a variety of ways. For example, the network 106 may interface by optical and/or electronic interfaces, and/or may use a plurality of network topographies and/or protocols including, but not limited to, Ethernet, TCP/IP, circuit switched paths, and/or combinations thereof. For example, the network 106 may be implemented as the World Wide Web (or Internet), a local area network (LAN), a wide area network (WAN), a metropolitan network, a wireless network, a cellular network, a GSM-network, a CDMA network, a 3G network, a 4G network, a satellite network, a radio network, an optical network, a cable network, a public switched telephone network, an Ethernet network, and/or combinations thereof. Additionally, the network 106 may use a variety of network protocols to permit bi-directional interface and/or communication of data and/or information between the first host system 102, the second host system 126, and/or one or more user terminals 104.

[0043] Referring to FIGS. 1 and 2, the one or more memories 110 may store processor executable code and/or information comprising a user database 136, a contractor database 137, a first image database 138 and program logic 139. The

processor executable code may be stored as a data structure, such as a database and/or a data table, for example.

[0044] The user database 136 may include information about customers engaging with the first host system 102. For example, one or more customers may access the first host system 102 through the one or more user terminals 104. The first host system 102 may provide a roof request website to the user terminal 104. The roof request website may be directed by the one or more processors 108. The processor 108 may also direct the one or more customers to a login/registration portion of the website.

[0045] In some embodiments, customers may register a user profile with the first host system 102. The user profile may be created and/or stored in the user database 136 by the processor 108. For example, the customer may be prompted by the processor 108 to provide login credentials (e.g., username and/or password). Login credentials may allow the processor 108 to authenticate the customer against the user database 136. In this manner, the first host system 102 may access the user profile in the user database 136. The user profile may include information including, but not limited to, demographic information including, but not limited to, name, age, address, billing account information, username, password, behavioral information, experience, gender, and/or the like.

[0046] If user authentication is successful, the user profile may be accessed by the processor 108. If the user authentication fails, the customer may be returned to the login/registration page, where the customer may be prompted for a username and

password again. Optionally, the processor 108 may block a customer from entering a username and/or password after a preset number of failed authentication attempts.

[0047] In some embodiments, customers may be prompted by the processor 108 to provide information for a user profile without registration and/or authentication using a username and/or password. The user profile may be created and/or stored in the user database 136 by the processor 108. For example, the processor 108 may prompt the customer to provide demographic information (e.g., name, address, billing account information, and the like), and store the information in a user profile for the customer using a unique customer identification.

[0048] The contractor database 137 may comprise information about roofing contractors within a given geographic location. Each roofing contractor may be associated with a contractor profile having information including, but not limited to, roofing contractor business name, roofing contractor owner name, address, experience level, age of contractor business, review information, and the like. In some embodiments, the contractor profile may include a geographical category assignment identification (ID). For example, the contractor profile may be assigned a numerical or alphabetical identification based on geographic location of the business.

[0049] In some embodiments, the contractor profile may include review information. The review information may include positive and/or negative feedback relating to each contractor. For example, the review information may be based on prior customer feedback of customers using the system 100. Review information may also be obtained from one or more outside databases (e.g., Yelp, Google review, and/or the like).

[0050] One or more contractors may provide a contractor profile via the first host system 102. For example, one or more contractors may access the roof review website of the first host system 102 via the user terminal 104. The processor 108 may direct the contractor via the roof review website to a login/registration portion of the website. If the contractor has previously registered with the first host system 102, the contractor may be prompted by the processor 108 to provide login credentials (e.g., username and/or password), which may allow the processor 108 to authenticate the contractor against the contractor database 137.

[0051] If the contractor is not registered with the first host system 102, the first host system 102 may prompt the contractor to provide information via the one or more user terminals 104 to create a contractor profile. Alternatively, the contractor profiles may be provided in the contractor database 137 without information provided by each contractor. For example, a user of the first host system 102 may provide information via the input device 112, the network 106, and/or the like, setting up a contractor profile without direct knowledge of the contractor.

[0052] The one or more memories 110 may include the image database 138. The image database 138 may store geo-referenced imagery. Such imagery may be represented by a single pixel map, and/or by a series of tiled pixel maps that when aggregated recreate the image pixel map. Imagery may include nadir, ortho-rectified and/or oblique geo-referenced images. The one or more processors 108 may provide the images via the image database 138 to customers at the one or more user terminals 104. Customers, using the user terminals 104, may provide geographic location information associated with a roof request using the geo-referenced images provided by

the one or more processors 108. For example, a customer may be provided a geo-referenced image to validate the location of a structure (e.g., roof). In some embodiments, the customer may be able to select the structure (e.g., via a drag-and-drop user interface) to pinpoint a location of the structure within the image. Selection of the structure may provide location information (e.g., latitude/longitude coordinate, or and the like) of the structure to the first host system 102. For simplicity, the description will provide for a roof as the structure of interest. However, is should be apparent that other structures of buildings and/or landscapes may be used in accordance with the present disclosure.

[0053] The one or more memories 110 may further store processor executable code and/or instructions, which may comprise the program logic 139. The program logic 139 may comprise processor executable instructions and/or code, which when executed by the processor 108, may cause the processor 108 to generate, maintain, provide, and/or host a website providing one or more roofing requests, for example. The program logic 139 may further cause the processor 108 to collect user information and/or contractor information, create user profiles and/or contractor profiles, provide users one or more geo-referenced images, and allow one or more users to validate a location of the roof as described herein.

[0054] The one or more processors 108 may generate, maintain, or provide one or more roofing orders to the second host system 126. For example, the one or more processors 108 may provide the one or more roofing orders to the second host system 126 by copying information obtained and/or stored in one or more memories 110. The

roofing orders may include contractor profile, user profile, user validated images, a unique ordering ID, and/or the like.

[0055] The one or more memories 130 of the second host system 126 may store processor executable code and/or information comprising an order database 140, a second image database 141 and the program logic 142. The processor executable code may be stored as a data structure, such as a database and/or a data table, for example.

[0056] The order database 140 may include information about a roofing order placed by a customer and copied by the first host system 102. For example, a roofing order may include contractor profile, user profile, user validated images, a unique ordering ID, and/or the like. The second host system 126 may access the order database 140 to provide a roofing report as described in detail herein.

[0057] The one or more memories 130 of the second host system 126 may also include a second image database 141. The second image database 141 may provide additional nadir, ortho-rectified, and/or oblique geo-referenced and/or non-geo-referenced images for use in providing a roofing report as described in detail herein. Alternatively, the image database 138 and the image database 141 may be the same database.

[0058] The one or more memories 130 of the second host system 126 may further store processor executable code and/or instructions, which may comprise program logic 142. The program logic 142 may comprise processor executable instructions and/or code, which when executed by the one or more processors 128, may cause the one or more processors 128 to generate, maintain, and/or provide a website

or series of websites for providing roofing reports. The program logic 142 may further cause the one or more processors 128 to allow one or more users to participate in executing a roofing report via the input devices 132.

[0059] Referring to FIG. 3, shown therein is an exemplary flow chart 144 of program logic 139 for creating a roof report order which may be used with the first host system 102 according to the instant disclosure. Program logic 139 may comprise executable code, which when executed by the one or more processors 108 may cause the one or more processors 108 to execute one or more of the following:

[0060] The program logic 139 may provide for one or more user terminals 104 interfacing with the processor 108 over the network 106 to provide one or more roofing request website pages allowing customers to place a roofing request order. Each order is generally a request of the customer to provide estimated square footage of a specific roof. Additionally, each order may also include a request for contractor information and/or a bid request for estimate costs and associated features of materials, supplies, physical labor, and the like.

[0061] Generally, in a step 145, customers using one or more user terminals 104 may provide user information to the first host system 102. The user information may then be used to prepare one or more user profiles for use in preparing the roofing report. Additionally, program logic 139 may generate a unique identification number and/or alpha numeric character to associate with the user profile.

[0062] The user information may include a location of the roof provided by the customer. For example, the customer may provide a residential and/or commercial address of the roof. One or more processors 108 may direct customers to validate the

location of the roof using user terminals 104, in step 146. For example, processors 108 may provide one or more images via the image database 138. The images may be geo-referenced images illustrating portions or all of the roof. The program logic 139 may cause the processor 108 to provide users the one or more geo-referenced images, and allow the customer to validate the location of the roof. For example, the customer may be able to use a drag-and-drop element provided by the program logic 139 via user terminal 104 to select the roof within the one or more geo-referenced images. Selection of the roof within the one or more geo-referenced images may provide one or more validated images and a validated location of the roof. In some embodiments, the geographic location may include coordinates, and validation of the geographic location may be provided by a customer by altering one or more coordinates of the geographic location. Customers may alter the one or more coordinates by methods including, but not limited to, manual manipulation, drag-and-drop elements, and the like.

[0063] It should be understood that validation of the geo-referenced images may be provided by the second host system 126 via the one or more processors 128 in lieu of, or in combination with host system 102. For example, the first host system 102 may direct customers to the second host system 126 wherein the one or more processors 128 of the second host system 126 provide geo-referenced images from image database 141 to the customer for validation of one or more roof and/or roofing structures. As such, in some embodiments, only the second host system 126 provides geo-referenced images in the image database 141.

[0064] The first host system 102 may determine contractor availability within a region of interest about the validated location of the roof as shown in step 147. For

example, program logic 139 may extract the validated location and compare the validated location against location of contractors in a region of interest. The region of interest may be determined by the customer via user terminal and/or the region of interest may be a pre-programmed determination. For example, the region of interest may be a five mile radius about the validated location. Contractor availability may include contractors having a contractor profile within the contractor database 137. Contractors within the contractor database 137 may be provided with a copy of the roofing report as described herein.

[0065] The program logic 139 may direct the one or more processors 108 to create and/or store a roofing order for the customer as shown in step 148. Additionally, the program logic 139 may direct one or more processors to transfer the roofing order to the second host system 126.

[0066] FIG. 4 illustrates a flow chart 149 of an exemplary embodiment of the program logic 139 and/or 142 for processing a roof report order which may be used with the system 100 according to the instant disclosure. The program logic 139 comprises processor executable code, that when executed by the processor 108, may cause the processor 108 to execute one or more of the following:

[0067] The program logic 139 may include a step 150 wherein one or more user terminals 104 interfacing with the processor 108 over the network 106 may be provided with one or more websites having a mechanism allowing a customer to request a roof report. The customer may provide the request to the first host system 102 using the one or more websites, in a step 152. Prior to providing customer information, the customer may be notified that the first host system 102 may distribute any contact

information provided by the customer to contractors provided within the first host system 102. The one or more processors 108 may provide the customer an option for agreeing to terms of service (e.g., distribution of their contact information), in a step 154.

[0068] In a step 156, the roof report request website may include queries regarding customer information including, but not limited to, customer name, address, address of the roof, billing information, and the like. The customer information may be provided by the one or more processors 108 and stored in the one or more memories 110. For example, the customer information may be provided by processors 108 as a user profile and stored in the user database 136 of the one or more memories 110.

[0069] Customers may be able to select the desired roof, location, and/or the like on the one or more websites provided by the processor 108 over the network 106, in step 158. For example, the customer may use the one or more user terminals 104 to provide a geographical location (e.g., address, latitude/longitude coordinates, or the like), a geo-referenced image, and/or an element within a geo-referenced image. Once the geographical location of the roof is selected, the processor 108 may provide a verification web page or similar mechanism for customer review and/or approval of a proposed order, in a step 160. The first host system 102 may receive the proposed order via the processor 108, store the order and/or transfer the order to the second host system 126 for processing, in a step 162. The processor 108 may provide a confirmation webpage or similar mechanism informing the customer of a successful order placement, in a step 164.

[0070] FIG. 5 illustrates a flow chart 169 of an exemplary embodiment of the program logic 139 and/or 142 for providing a roof report which may be used with the

system 100 according to the instant disclosure. Generally, processing of the proposed order may be provided using the second host system 126. The program logic 142 comprises processor executable code, that when executed by the processor 128, may cause the processor 128 to execute one or more of the following:

[0071] The second host system 126 may receive the proposed order via the one or more processors 108 of the first host system 102. Generally, the validity of the location of the roof provided by the customer may be determined, in a step 170. In a step 172, the second host system 126 may determine if the location of the roof provided by the customer exists. If the location is not found, the customer may be further contacted by the second host system 126 and/or the first host system 102 requesting resubmission or additional information for the proposed order, in a step 174. Additionally, in a step 176, the second host system 126 may determine if corresponding imagery within image database 141 exists for the location provided by the customer. If there is no corresponding imagery, the customer may be further contacted by the second host system 126 and/or the first host system 102 with a status message indicating no suitable imagery of the roof currently exists, in a step 178.

[0072] The second host system 126 may further process and review the order, in a step 180. An exemplary series of steps for implementing step 180 is shown in a flow chart 188 illustrated in FIG. 6. For example, the one or more processors 128 of the second host system 126 may receive the proposed order, in a step 190. The one or more processors 128 may extract order related information and images. Generally, a user may access a roof report website provided by the one or more processors 128 to review and/or process the proposed order. For example, the user may access the roof

report website using the input devices 132 and the output devices 134 to review and/or process the proposed order.

[0073] In some embodiments, using the input devices 132 and/or the output devices 134, the user may provide additional details to the proposed order regarding the roof including, but not limited to, identification of areas of the roof (e.g., eaves, drip edges, ridges, and the like), pitch, distance, angle, and/or the like.

[0074] The footprint of the roof may be determined, in step 192. For example, the footprint of the roof may be determined using systems and methods including, but not limited to, those described in U.S. Patent Publication No. 2010/0179787, U.S. Patent Publication No. 2010/0110074, U.S. Patent Publication No. 2010/0114537, U.S. Patent Publication No. 2011/0187713, U.S. Patent No. 8,078,436, and U.S. Serial No. 12/090,692, all of which are incorporated by reference herein in their entirety.

[0075] In some embodiments, the one or more processors 128 may provide one or more websites to the user for evaluation of multiple oblique images to provide the footprint of the roof. For example, the user and/or the processors 128 may identify edges of the roof. Two-dimensional and/or three-dimensional information regarding the edges (e.g., position, orientation, and/or length) may be obtained from the images. Using the two-dimensional and/or three-dimensional information (e.g., position orientation, and/or length), line segments may be determined with multiple line segments forming at least a portion of the footprint of the roof.

[0076] The footprint may provide a two-dimensional boundary and/or outline of the roof. In a step 194, a predominant pitch value for the roof may be determined. In some embodiments, a predominant pitch value may be determined using the footprint

as a boundary of the roof. The predominant pitch may be a weighted average of individual pitch factors for two or more portions of the roof. FIG. 7 illustrates an exemplary slope factor chart for determining pitch factors. For example, a first portion of the roof (e.g., 60% of the roof) may be at a 6:12 pitch. The 6:12 pitch corresponds to 1.1180 as the pitch factor). A second portion of the roof (e.g. 40% of the roof) may be at a 4:12 pitch. The 4:12 pitch corresponds to 1.0541 as the pitch factor. Thus, the weighted value of the first portion of the roof having 6:12 pitch is:

(Pitch Factor) * (Percentage of roof) = First Weighted Value **EQ. 1**

1.1180 * 0.6 = 0.6708

The weighted value of the second portion of the roof having 4:12 pitch is:

(Pitch Factor) * (Percentage of roof) = Second Weighted Value **EQ. 2**

1.0541 * 0.4 = 0.42164

The sum of 0.6708 and 0.42164 is 1.09244 as the total weighted pitch value. A total weighted pitch value of 1.09244 is closest to a pitch factor of 1.0833 in the table in FIG. 7. This pitch factor corresponds to a 5:12 pitch. As such, the predominant pitch in this scenario would be 5:12. Using the predominant pitch and outer dimensions provided by the footprint, an estimated area of the roof may be determined, in a step 196.

[0077] In some embodiments, the user may review and reevaluate the estimated area of the roof obtained. For example, using the system and methods described

herein, the user may review the steps for obtaining the footprint, the predominant pitch value, and/or estimated area. Additionally, the user may provide for a review report. The review report may comprise feedback to the one or more processors 128 regarding errors, concerns, and/or the like.

[0078] Referring to FIGS. 1, 6 and 8, in a step 184 and 186, a customer and/or contractor may receive a roof report 200. FIG. 8 illustrates an exemplary embodiment of a roof report 200 provided in accordance with the present disclosure. The program logic 139 may provide for one or more user terminals 104 interfacing with the processor 108 over the network 106 to provide one or more roofing report website pages allowing customers and/or contractors to view the roof report 200.

[0079] Generally, roofing reports within the industry are detailed with data sets regarding pitch, total area, eave length, hip ridge length, valley length, number of box vents, and the like. The roof report 200 may be streamlined to generally include data sets such as customer information 202, roofing 204, estimated area detail 206, and contractor(s) 208. The customer information data set 202 may include the customer name, customer contact information, and the like. The roofing data set 204 may include one or more nadir images of the roof and one or more oblique images of the roof. The estimated area detail 206 may provide the total estimated roof area as determined using the second host system 126 described herein. The contractor data set 208 may include one or more contractor names and associated contractor contact information for the one or more contractor names.

[0080] The roof report 200 may be distributed using the first host system 102 and/or the second host system 126 to the one or more user terminals 104. For

example, the roof report 200 may be distributed using the first host system 102 to a contractor at a first user terminal 104 and the roof report 200 may be distributed using the first host system 102 to the customer at a second user terminal 104.

[0081] In some embodiments, the first host system 102 and/or the second host system 126 may distribute the roof report 200 to one or more recipients in addition to, or in lieu of, the customer. For example, the roof report 200 may be distributed to recipients including, but not limited to, roof material suppliers (e.g., small roofing companies, Lowes, Home Depot, and the like), insurance companies, real estate agencies, home services and/or cleaning companies, insulation companies, auditing companies, and/or contractors. Contractors and/or suppliers may be associated with residential and/or commercial building elements and/or services including, but not limited to, fireplaces, pool sales, fencing, lawn maintenance, gardening, pavement resurfacing, decking, sunrooms, roofing, guttering, custom Christmas light designs, siding, windows, doors, garage doors, and the like.

[0082] In some embodiments, additional data sets may be included within the roof report 200. For example, data sets may include, but are not limited to, weather data, insurance/valuation data, census data, school district data, real estate data, and the like.

[0083] Weather data sets may be provided by one or more databases storing information associated with weather (e.g., inclement weather). A weather data set within the roof report 200 may include, but is not limited to, hail history information and/or location, wind data, severe thunderstorm data, hurricane data, tornado data, and/or the like. In some embodiments, the one or more databases providing weather

information may be hosted by a separate system (e.g., LiveHailMap.com) and provide information to the first host system 102 and/or the second host system 126. The weather data set may be included within the roof report 200 and provided to the customer and/or other parties. In some embodiments, weather data sets may be provided within a report as described herein without the addition of roof related information (e.g., roofing data set 204).

[0084] Insurance and/or valuation data sets may be provided by one or more databases storing information associated with housing insurance and/or valuation. An insurance and/or valuation data set may include, but is not limited to, insured value of the home, insurance premium amount, type of residence (e.g., multi-family, single family), number of floors (e.g., multi-floor, single-floor), building type, and/or the like. In some embodiments, the one or more databases may be hosted by a separate system (e.g., Bluebook, MSB, 360Value) and provide information to the first host system 102 and/or the second host system 126.

[0085] The insurance and/or valuation data set may be included within the roof report 200 and provided to the customer and/or other parties. For example, during underwriting of a home, an insurance company may be able to request the roof report 200 on a home that is recently purchased. The information within the roof report 200 may be integrated with insurance information provided by an insurance database and used to form a quote report. The quote report may be sent to the customer and/or insurance company. Alternatively, the roof report 200 may be solely sent to the insurance company with the insurance company using the information to formulate a quote.

[0086] In another example, the roof report 200 may be used in an insurance claim. In the case of a catastrophe of a customer, one or more databases may be used to provide an insurance dataset with claim information in the roof report 200. For example, an insurance database having a policy in force (PIF) and a weather database may be used to correlate information regarding an insurance claim for a particular roof. This information may be provided within the roof report 200.

[0087] Real estate and/or census data sets may also be including within the roof report. The real estate and/or census data sets may be provided by one or more databases having detailed information of a home. For example, a real estate data set may include, but is not limited to, the homeowner's name, the purchase price of the home, number of times the home has been on the market, the number of days the home has been on the market, the lot size, and/or the like. The census data set may include information concerning the number of residents within the home. In some embodiments, the one or more databases may be hosted by a separate system (e.g., Core Logic) and provide information to the first host system 102 and/or the second host system 126 to provide data sets as described herein. The real estate data set may be included within the roof report 200 and provided to the customer and/or other parties.

[0088] The roof reports 200 may include roofing data as described herein; however, system 100 may be used to provide other information to a customer and/or other party without roof related information (e.g., roofing data set 204). For example, in a real estate transaction, one or more databases in host system 102 and/or host system 126 may include recent home sales over time in one or more geographic areas. The footprint of each home and home valuation may be provided in one or more databases

within host system 102 and/or host system 126. Using the systems and methods described herein, a customer (e.g., homeowner) may request a report determining approximate sales price of a home using the footprint and/or valuation versus comparables within the geographic area. The report may provide an approximate sale price of the home. In some embodiments, demographics of the homeowners may be used and stored in one or more databases. The demographic information may be used for potential advertising and/or comparables within the geographic area.In another example, using systems and methods as described herein, a report may be provided for housecleaning and/or home services area (e.g., fireplace cleaning, pool sales, fencing, lawn maintenance/gardening, pavement resurfacing, decking, sunrooms, roofing, guttering, custom Christmas light designs, siding, windows, doors, garage doors, and the like). For example, using a footprint of a home, number of stories within a home, and the like, a determination of average square footage within a home may be determined. This information may be used to formulate a price quote for cleaning services.

[0089] Other services related to roofing may be provided within the roof report 200. For example, using the square footage of the roofing footprint, a price quote may be generated on the cost of insulation for the roof (e.g., energy efficiency, insulation replacement, and the like). Additionally, audits may be performed using information within one or more databases. For example, using the roofing area of a home, historically paid insurance claims for comparables, and validation of payment for a specific claim for the home, a comparison may be made to determine whether the

service payment for the specific claim was within a certain threshold. Auditing, it should be understood, may be applied to other areas as described herein as well.

[0090] Although the terms "home" and "house" are used herein, it should be noted that the systems and methods in the present disclosure may be applied to any residential and/or commercial building or structure.

[0091] From the above description, it is clear that the inventive concept(s) disclosed herein is well adapted to carry out the objects and to attain the advantages mentioned herein as well as those inherent in the inventive concept(s) disclosed herein. While presently preferred embodiments of the inventive concept(s) disclosed herein have been described for purposed of this disclosure, it will be understood that numerous changes may be made which will readily suggest themselves to those skilled in the art and which are accomplished within the scope and spirit of the inventive concept(s) disclosed herein and defined by the appended claims.

What is claimed is:

1. A set of instructions stored on one or more computer readable medium for running on one or more computer systems, comprising:

instructions for identifying a geographic location of a roof;

instructions for determining contact information of one or more contractors within a region of interest of the geographic location of the roof; and,

instructions for determining a footprint of the roof;

instructions for determining predominant pitch of the roof;

instructions for determining an estimated roofing area based on the predominant pitch and the footprint of the roof.

2. The set of instructions of claim 1, further comprising instructions for providing a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractor within the region of interest of the geographic location of the roof.

3. The set of instructions of claim 2, wherein the roof report includes contact information of the customer.

4. The set of instructions of claim 1, wherein the one or more computer readable medium comprises a first computer readable medium of a first host system and a second computer readable medium of a second host system.

5. The set of instructions of claim 1, wherein instructions for identifying the geographic location of the roof further comprises instructions for obtaining contact information of a customer.

6. The set of instructions of claim 1, wherein the one or more computer readable medium further comprises instructions for receiving customer input to validate geographic location of the roof.

7. The set of instructions of claim 6, wherein the geographic location includes coordinates and validation of the geographic location includes instructions for receiving customer input to alter one or more coordinates of the geographic location.

8. The set of instructions of claim 1, wherein instructions for identifying a geographic location of the roof includes identifying one or more edges of the roof in an image.

9. The set of instructions of claim 1, wherein instructions for determining a footprint of the roof further comprises:

instructions for identifying edges of the roof;

instructions for determining three-dimensional information of the edges including position, orientation and length using multiple oblique images from multiple cardinal directions; and,

instructions for determining, automatically, one or more line segments forming a portion of a footprint of the roof utilizing position and orientation of the edges.

10. The set of instructions of claim 1, wherein determining the predominant pitch includes determining a plurality of pitch values, the predominant pitch based on the plurality of pitch values.

11. The set of instructions of claim 10, wherein each pitch value is associated with an estimated percentage of roof area to provide an average pitch value.

12. The set of instructions of claim 1, further comprising:

instructions for providing the roof report to one or more contractors, the contractor located within the region of interest of the geographic location of the roof.

13. A system, comprising:

two or more host systems, each host system having one or more computer readable medium; the first host system storing a set of instructions that when executed by one or more processors causes the one or more processors to:

identify a geographic location of a roof;

determine contact information of at least one contractor within a region of interest about the geographic location of the roof;

the second host system storing a set of instructions that when executed by one or more processors causes the one or more processors to:

determine a footprint of the roof;

determine a predominant pitch;

determine an estimated roofing area based on the predominant pitch and the footprint of the roof; and,

provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractors within the region of interest.

ABSTRACT

A set of instructions stored on one or more computer readable medium for running on one or more computer systems is described herein. The set of instructions generally may include instructions for identifying a geographic location of a roof, instructions for determining contact information of one or more contractors within a region of interest of the geographic location of the roof, instructions for determining a footprint of the roof, instructions for determining predominant pitch of the roof, and/or instructions for determining an estimated roofing area based on the predominant pitch and the footprint of the roof.

Electronically Filed: 03/19/2012
Title: A Method and System for Quick Square Roof Reporting
Inventor: Chris Thornberry
Attorney: Marc A. Brockhaus Dkt. No. 6338.157
SHEET 1 OF 9 FORMAL DRAWINGS

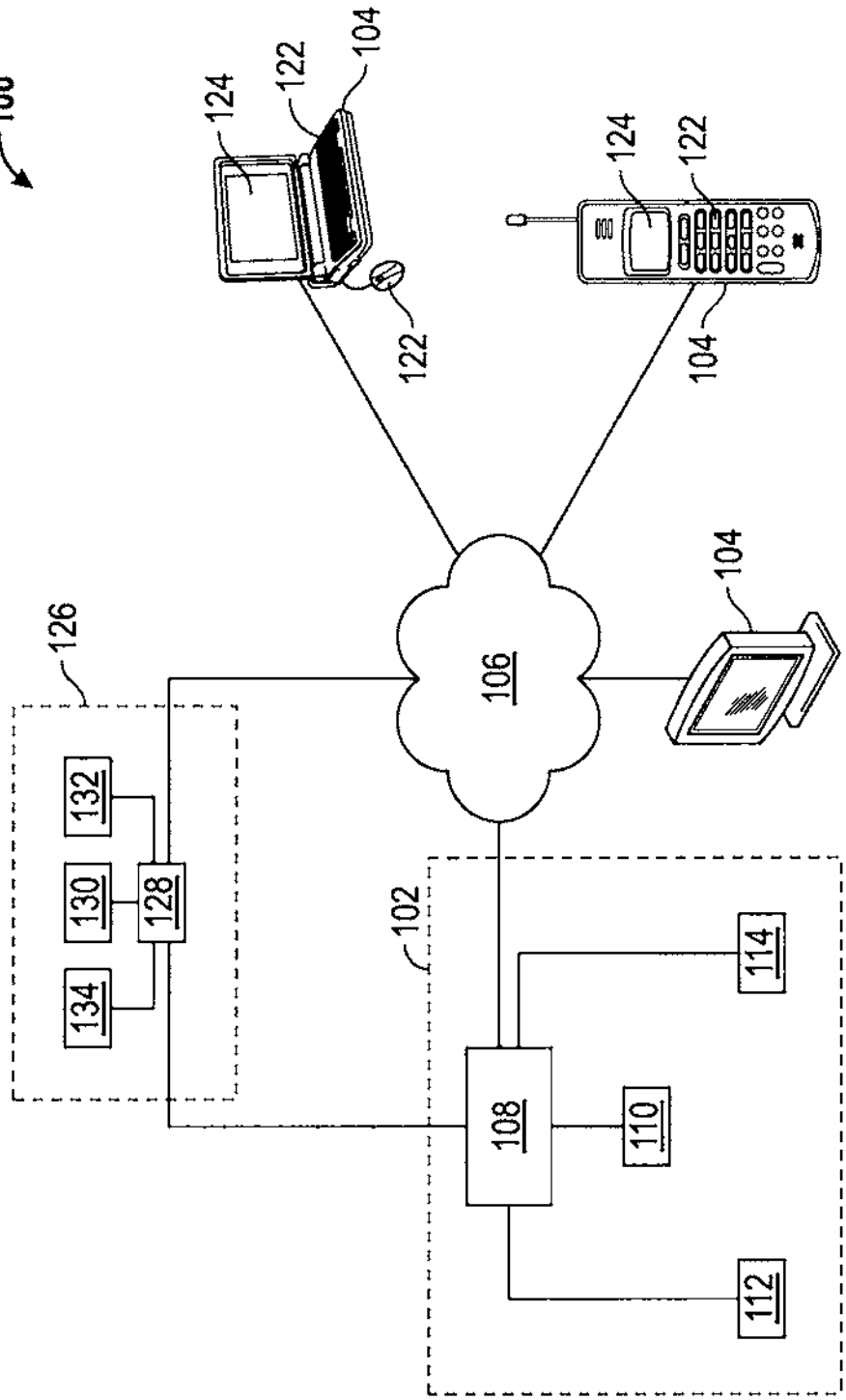


FIG. 1

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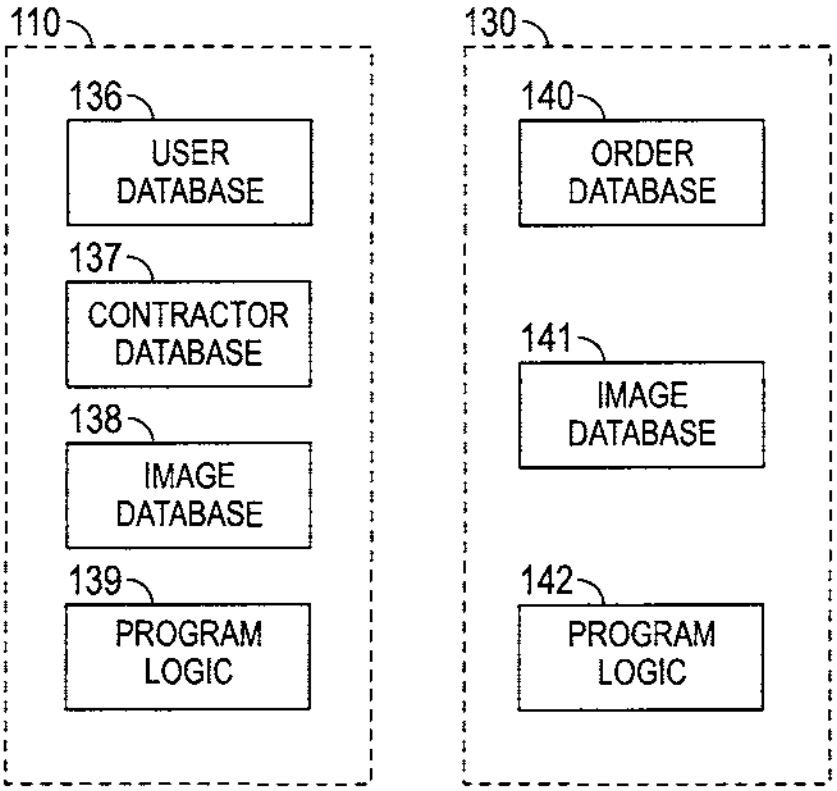


FIG. 2

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Inventor: Chris Thornberry
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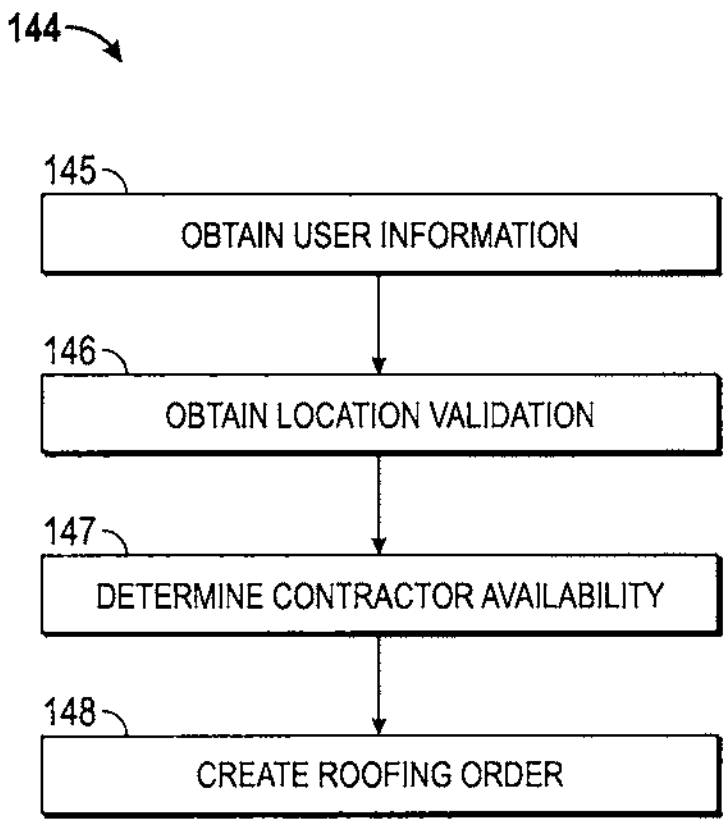


FIG. 3

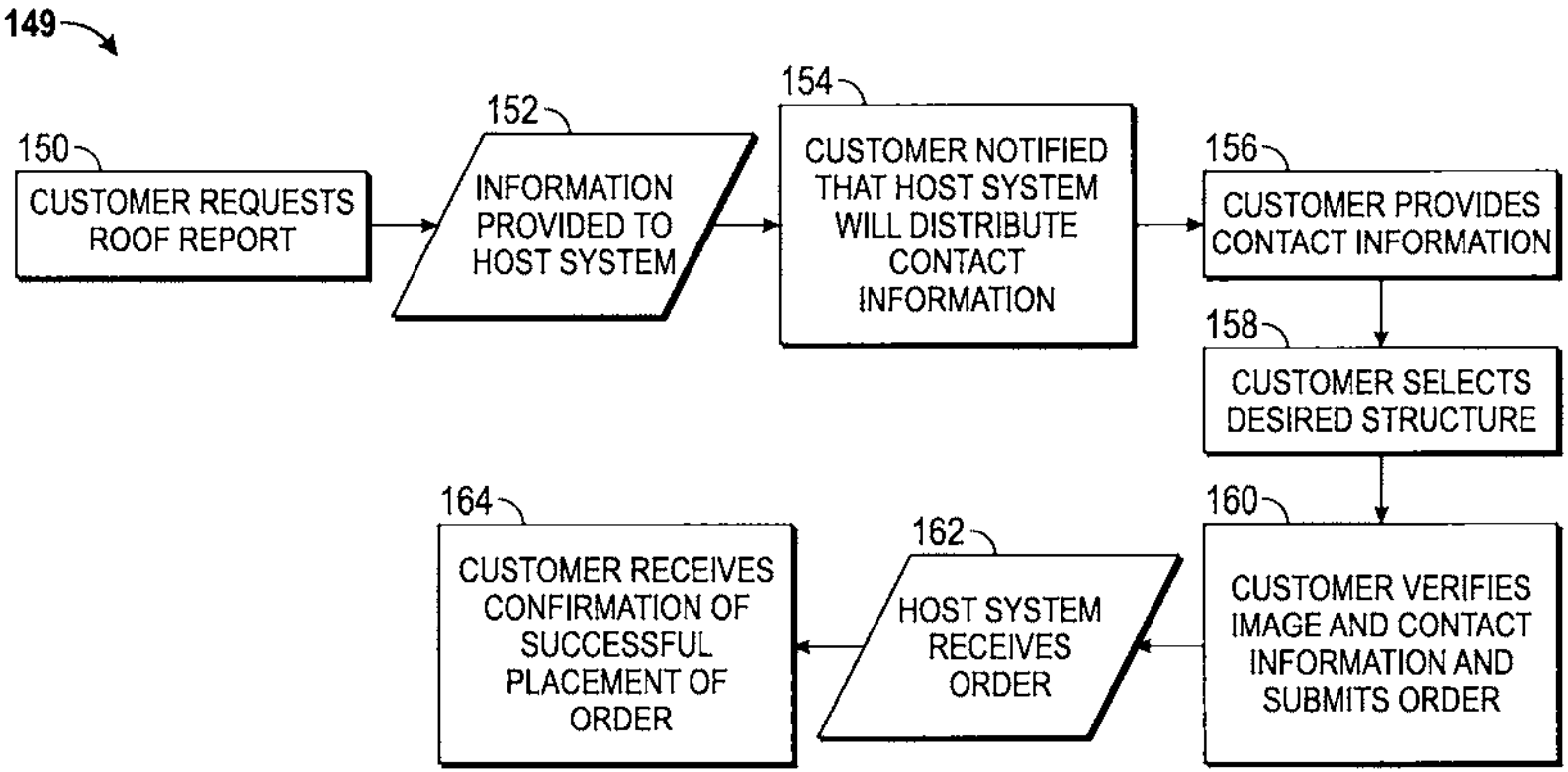


FIG. 4

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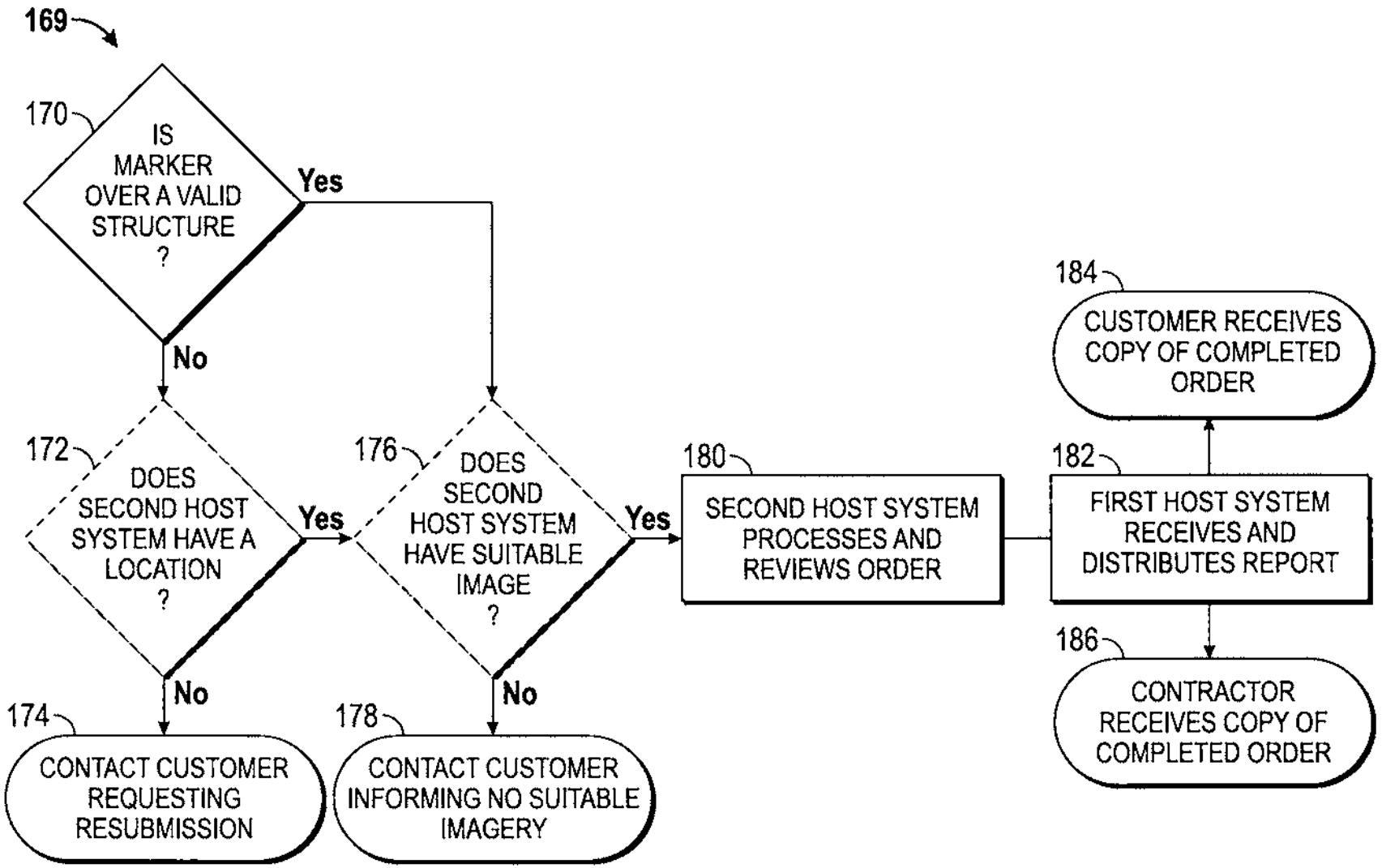


FIG. 5

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Attorney: Marc A. Brockhaus Dkt. No. 6338.157
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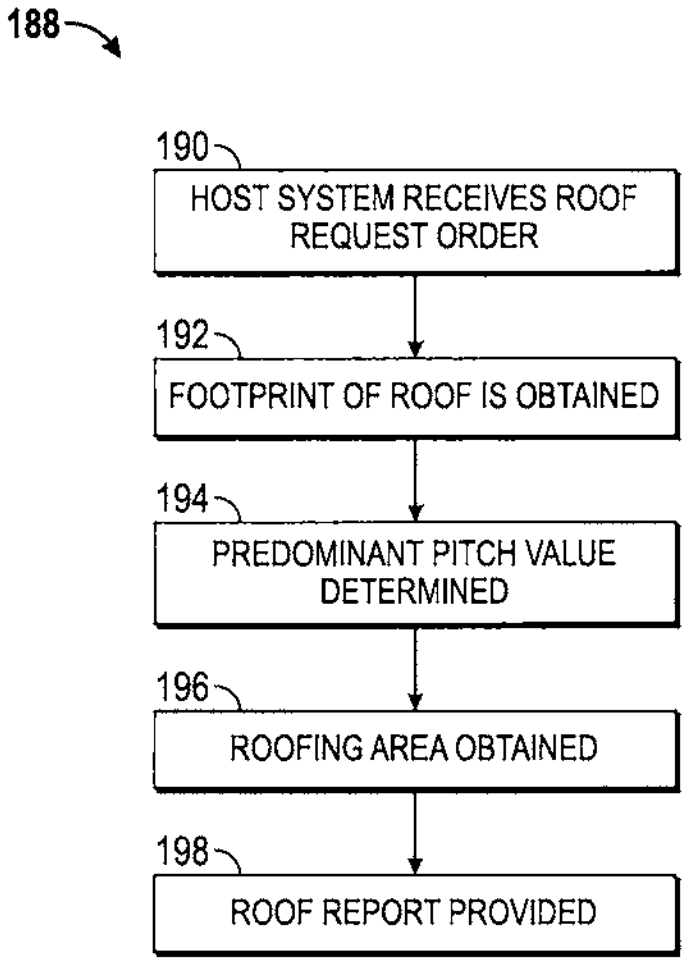


FIG. 6

Slope Factor Chart

Pitch of Roof	1:12	2:12	3:12	4:12	5:12	6:12	7:12	8:12	9:12	10:12	11:12	12:12
Slope Factor	1.0035	1.0138	1.0308	1.0541	1.0833	1.1180	1.1577	1.2019	1.2500	1.3017	1.3566	1.4142

(A) x (Slope Factor) = (B)

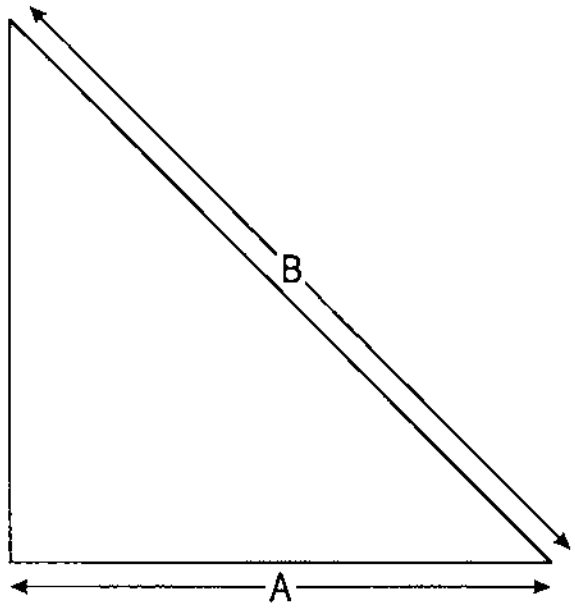
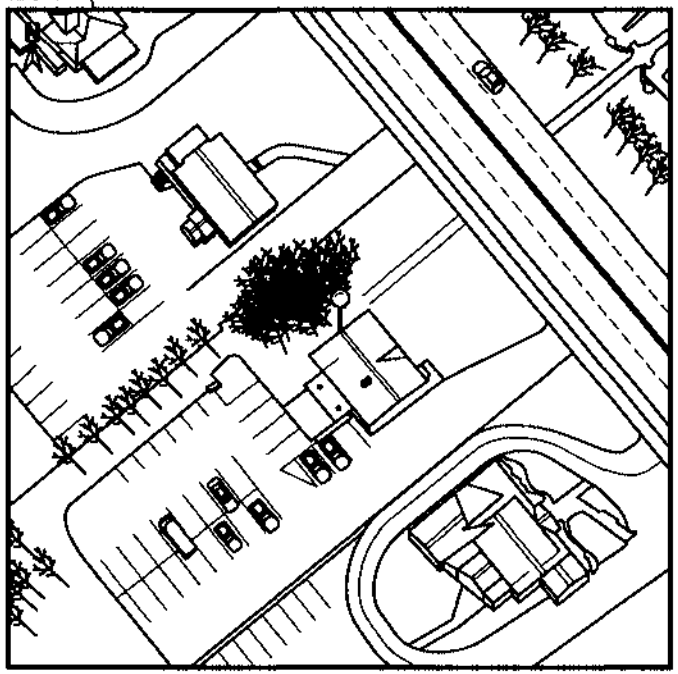


FIG. 7

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Inventor: Chris Thornberry
Attorney: Marc A. Brockhaus Dkt. No. 6338.157
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200

202

John Homeowner
1440 Monroe Ave
Rochester NY, 14618
123-456-7890
homeowner@gaf.com

Congratulations!

You have received a Pictometry Roof Squares Report compliments of GAF. This report provides an estimate of the number of squares on your roof.

REPORT DETAILS : INTRODUCTION

HOMEOWNER

John Homeowner	Order # : PIC-000012840
1440 Monroe Ave	Phone : 123-456-7890
Rochester NY, 14618	Email : homeowner@gaf.com

202

REPORT BY GAF Pictometry formerly GeoEstimator
Find out more: GeoEstimator.com

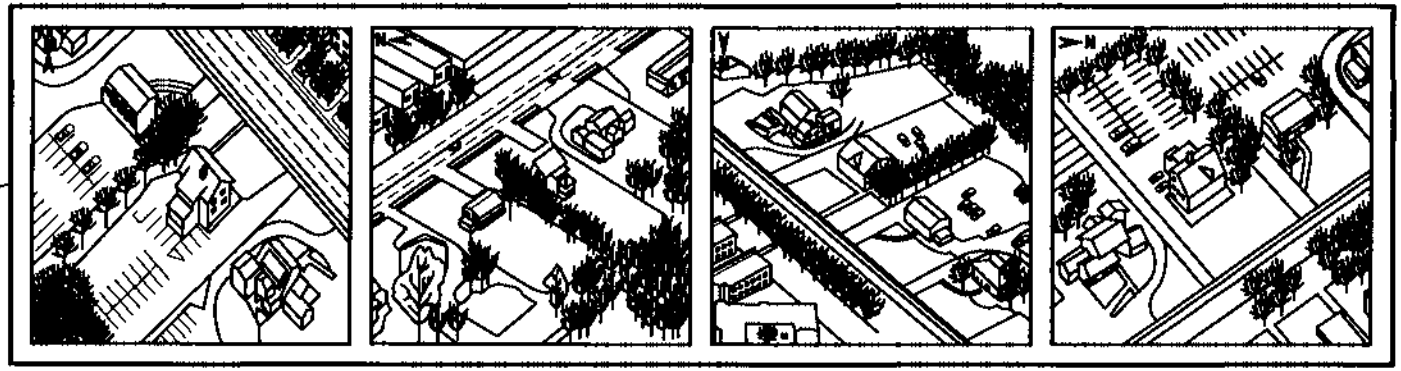
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FIG. 8

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GAF



204

200

206 Your roof is estimated at **20.2 squares***+/- 10%

208

A copy of your report is being sent to the following GAF Master Elite Contractors who will be able to provide a quotation for installation services.

Contractor 1
123 Main Street
Anywhere, MY 11735
800Contractor1

Contractor 2
456 Main Street
Anywhere, MY 107470
800Contractor2

*DISCLAIMER: The information contained in this report is for estimating purposes, and should be verified by a roofing professional. Use of this report is subject to terms and conditions found at www.pictometry.com/roof.

REPORT DETAILS : INTRODUCTION

HOMEOWNER

John Homeowner
1440 Monroe Ave
Rochester NY, 14618

Order # : PIC-000012840
Phone : 123-456-7890
Email : homeowner@gaf.com

REPORT BY Pictometry formerly GeoEstimator
Find out more: GeoEstimator.com

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FIG. 8 (Continued)

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Inventor: Chris Thornberry
Attorney: Marc A. Brockhaus Dkt. No. 6338.157
SHEET 9 OF 9 FORMAL DRAWINGS

Doc Code: Oath
Document Description: Oath or declaration filed

PTO/SB/01 (04-09)
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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☐ Declaration Submitted With Initial Filing OR ☐ Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required)

Attorney Docket Number	6338.157
First Named Inventor	Chris Thornberry
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Art Unit	
Examiner Name	

I hereby declare that: (1) Each inventor's residence, mailing address, and citizenship are as stated below next to their name; and (2) I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention titled:

A Method and System for Quick Square Roof Reporting

(Title of the Invention)

the application of which

☑ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) _____ as United States Application Number or PCT International Application Number _____ and was amended on (MM/DD/YYYY) _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

Authorization To Permit Access To Application by Participating Offices

☑ If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified patent application is filed access to the above-identified patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the above-identified patent application is filed to have access to the above-identified patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the above-identified patent application with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the above-identified patent application; and 3) any U.S. application-as-filed from which benefit is sought in the above-identified patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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DECLARATION — Utility or Design Patent Application

Claim of Foreign Priority Benefits

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application number(s) are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

Direct all correspondence to: ☑ The address associated with Customer Number: 30589 OR ☑ Correspondence address below

Name: Dunlap Codding, P.C.

Address: P.O. BOX 16370

City	State	Zip
Oklahoma City	Oklahoma	73113

Country	Telephone	Email
USA	405+607-8600	mbrockhaus@dunlapcodding.com

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application Files*. Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles*.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Chris T.	Thornberry

Inventor's Signature: | Date:

Residence: City	State	Country	Citizenship
Indianapolis	IN	USA	US

Mailing Address: 10825 Cyrus Dr.

City	State	Zip	Country
Indianapolis	IN	46231	USA

☐ Additional inventors or a legal representative are being named on the _____ supplemental sheet(s) PTO/SB/02A or 02LR attached hereto

PTO/SB/02A (07-07)
Approved for use through 01/31/2014. OMB 0651-0032
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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page _____ of _____

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Dale R.	Thornberry		
Inventor's Signature			Date
Carmel Residence: City	IN State	USA Country	US Citizenship
13890 Wildcat Dr. Mailing Address			
Carmel City	IN State	46033 Zip	US Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature			Date
Residence: City	State	Country	Citizenship
Mailing Address			
City	State	Zip	Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature			Date
Residence: City	State	Country	Citizenship
Mailing Address			
City	State	Zip	Country

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	A Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Douglas John Sorocco/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	95	95
Utility Search Fee	2111	1	310	310
Utility Examination Fee	2311	1	125	125
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**530**

Electronic Acknowledgement Receipt

EFS ID:	12339736
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	A Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Douglas John Sorocco/Lori Radford
Filer Authorized By:	Douglas John Sorocco
Attorney Docket Number:	6338.157
Receipt Date:	19-MAR-2012
Filing Date:	
Time Stamp:	17:47:18
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$530
RAM confirmation Number	5228
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal of New Application	6338157_Transmittal.pdf	83267 7a1ac04e88b0088d8886f95d88bd4a1fb93e37e8892	no	1
Warnings:					
Information:					
2		6338157_Application.pdf	1419540 2188044ad76bfbd90a72dcee807426b5ad16b1c270	yes	36
	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Specification		1	31	
	Claims		32	35	
	Abstract		36	36	
Warnings:					
Information:					
3	Drawings-only black and white line drawings	6338157_Drawings.pdf	238837 ce6ab7544dba991c28807daefb846e8750d17149066	no	9
Warnings:					
The page size in the PDF is too large. The pages should be 8.5 x 11 or A4. If this PDF is submitted, the pages will be resized upon entry into the Image File Wrapper and may affect subsequent processing					
Information:					
4	Oath or Declaration filed	6338157_Declaration.pdf	216172 8df86b71d952fa058a2c9d8dbb6aa2774bf64e116	no	4
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	33024 946ac01ed114e9c9985e4de2f0bac6891f8104ac761	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1990840		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/424,054	03/19/2012	Chris T. Thornberry	6338.157

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

IMPROPER AUTHORIZATION LETTER

OC000000053453114

Date Mailed: 04/02/2012

Title: Method and System for Quick Square Roof Reporting

Improper Submission of Authorization to Permit Access to Application by Participating Offices under 37 CFR 1.14(h)

The Authorization to Permit Access to Application by Participating Offices under 37 CFR 1.14(h) (authorization to permit access) on 03/19/2012 in application number 13/424,054 is not accepted because of the reason(s) listed below:

- The authorization to permit access was not properly signed. If applicant still wishes to provide authorization to permit access under 37 CFR 1.14(h), applicant must submit a properly signed authorization (e.g., PTO/SB/39).

Any authorization should be submitted prior to filing a subsequent foreign application with a participating intellectual property office in which priority is claimed to the above-identified U.S. application to ensure that it is likely that the participating foreign intellectual property office will be successful in its attempt to retrieve a copy of the U.S. priority application from the Office.

/mkibret/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/424,054	03/19/2012	3633	530	6338.157	13	2

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

FILING RECEIPT

OC000000053453110

Date Mailed: 04/02/2012

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Chris T. Thornberry, Indianapolis, IN;
Dale R. Thornberry, Carmel, IN;

Power of Attorney: None

Domestic Priority data as claimed by applicant

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 03/30/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/424,054**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
** **SMALL ENTITY** **

Title

Method and System for Quick Square Roof Reporting

Preliminary Class

052

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage, facilitate, and accelerate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 13/424,054

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	13 minus 20 =	*	x 30 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*	x 125 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	530		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x		OR	x	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x		OR	x	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x		OR	x	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x		OR	x	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/424,054	03/19/2012	Chris T. Thornberry	6338.157

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

FORMALITIES LETTER

OC000000053453111

Date Mailed: 04/02/2012

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The oath or declaration is unsigned.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of **$65** for a small entity in compliance with 37 CFR 1.27, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is **$65** for a small entity
- **$65** Surcharge.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
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Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Doc Code: TRAN.LET

Document Description: Transmittal Letter

PTO/SB/21 (07-09)
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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris Thornberry
Art Unit	3633
Examiner Name	
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☑ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please Identify below):

See Remarks

Remarks

ELECTRONICALLY TRANSMITTED:
1. SB21 Transmittal Form (1 pg);
2. SB22 Extension of Time (1 pg); and
3. SB01 Declaration (4 pgs).

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	DUNLAP CODDING, P.C.		
Signature	Marc Brockhaus		
Printed name	Marc A. Brockhaus		
Date	07/11/2012	Reg. No.	40,923

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Marc Brockhaus		
Typed or printed name	Marc A. Brockhaus	Date	07/11/2012

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) 6338.157
Application Number 13/424,054	Filed 03/19/2012
For METHOD AND SYSTEM FOR QUICK SQUARE ROOF REPORTING	
Art Unit 3633	Examiner

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	Fee	Small Entity Fee	
☐ One month (37 CFR 1.17(a)(1))	$150	$75	$
☑ Two months (37 CFR 1.17(a)(2))	$560	$280	$ 280.00
☐ Three months (37 CFR 1.17(a)(3))	$1270	$635	$
☐ Four months (37 CFR 1.17(a)(4))	$1980	$990	$
☐ Five months (37 CFR 1.17(a)(5))	$2690	$1345	$

☑ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check in the amount of the fee is enclosed.

☑ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number _____.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant/inventor.

☐ assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed (Form PTO/SB/96).

☑ attorney or agent of record. Registration Number 40,923

☐ attorney or agent under 37 CFR 1.34. Registration number if acting under 37 CFR 1.34 _____

Marc Brockhaus — Signature

07/11/2012 — Date

Marc A. Brockhaus — Typed or printed name

405-607-8600 — Telephone Number

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below.

☐ Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Doc Code: Oath
Document Description: Oath or declaration filed

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☐ Declaration Submitted With Initial Filing OR ☑ Declaration Submitted After Initial Filing (surcharge (37 CFR 1.16(f)) required)

Attorney Docket Number	6338.157
First Named Inventor	Chris Thornberry
COMPLETE IF KNOWN	
Application Number	13/424,054
Filing Date	03/19/2012
Art Unit	3633
Examiner Name	

I hereby declare that: (1) Each inventor's residence, mailing address, and citizenship are as stated below next to their name; and (2) I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention titled:

A Method and System for Quick Square Roof Reporting

(Title of the Invention)

the application of which

☐ is attached hereto

OR

☑ was filed on (MM/DD/YYYY) 03/19/2012 as United States Application Number or PCT International Application Number 13/424,054 and was amended on (MM/DD/YYYY) _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

Authorization To Permit Access To Application by Participating Offices

☑ If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified patent application is filed access to the above-identified patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the above-identified patent application is filed to have access to the above-identified patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the above-identified patent application with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the above-identified patent application; and 3) any U.S. application-as-filed from which benefit is sought in the above-identified patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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DECLARATION — Utility or Design Patent Application

Claim of Foreign Priority Benefits

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application number(s) are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

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Name: Dunlap Codding, P.C.

Address: P.O. BOX 16370

City	State	Zip
Oklahoma City	Oklahoma	73113

Country	Telephone	Email
USA	405+607-8600	mbrockhaus@dunlapcodding.com

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application Files*. Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles*.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

NAME OF SOLE OR FIRST INVENTOR: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Chris T.	Thornberry

Inventor's Signature: [signature] Date: 7/11/12

Residence: City	State	Country	Citizenship
Indianapolis	IN	USA	US

Mailing Address: 10825 Cyrus Dr.

City	State	Zip	Country
Indianapolis	IN	46231	USA

☐ Additional inventors or a legal representative are being named on the supplemental sheet(s) PTO/SB/02A or 02LR attached hereto

PTO/SB/02A (07-07)
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DECLARATION	ADDITIONAL INVENTOR(S) Supplemental Sheet Page ____ of ____

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Dale R.	Thornberry		
Inventor's Signature			Date 7/11/2012
Carmel Residence: City	IN State	USA Country	US Citizenship
13860 Wildcat Dr. Mailing Address			
Carmel City	IN State	46033 Zip	US Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature			Date
Residence: City	State	Country	Citizenship
Mailing Address			
City	State	Zip	Country

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor		
Given Name (first and middle (if any))	Family Name or Surname		
Inventor's Signature			Date
Residence: City	State	Country	Citizenship
Mailing Address			
City	State	Zip	Country

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Electronic Patent Application Fee Transmittal

Application Number:	13424054
Filing Date:	19-Mar-2012
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Marc Alan Brockhaus/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Late filing fee for oath or declaration	2051	1	65	65
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension - 2 months with $0 paid	2252	1	280	280
Miscellaneous:				
			Total in USD ($)	**345**

Electronic Acknowledgement Receipt

EFS ID:	13230528
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Marc Alan Brockhaus/Lori Radford
Filer Authorized By:	Marc Alan Brockhaus
Attorney Docket Number:	6338.157
Receipt Date:	11-JUL-2012
Filing Date:	19-MAR-2012
Time Stamp:	19:11:41
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$345
RAM confirmation Number	8318
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	6338157_Transmittal07112012.pdf	66328 6c90d1fcdcecfeb1488ba30454e7e7111f7f0e959	no	1
Warnings:					
Information:					
2	Extension of Time	6338157_Extension.pdf	63328 d8ca90b22ad0193f8ace4117744a883bd90ba89815	no	1
Warnings:					
Information:					
3	Oath or Declaration filed	6338157_Declaration07112012.pdf	251984 8589b28c8031226e67d81a90ab3fbd1934c09e	no	4
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	32029 713130fdbcda6a72aaa4974ca13cf3dc9a1c6c2	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	413669		

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/424,054	03/19/2012	3633	595	6338.157	13	2

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

UPDATED FILING RECEIPT

OC00000005542764O

Date Mailed: 07/18/2012

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Chris T. Thornberry, Indianapolis, IN;
Dale R. Thornberry, Carmel, IN;

Power of Attorney: None

Domestic Priority data as claimed by applicant

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

Permission to Access - A proper **Authorization to Permit Access to Application by Participating Offices** (PTO/SB/39 or its equivalent) has been received by the USPTO.

If Required, Foreign Filing License Granted: 03/30/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/424,054**

Projected Publication Date: 09/19/2013

Non-Publication Request: No

Early Publication Request: No
** **SMALL ENTITY** **

Title

Method and System for Quick Square Roof Reporting

Preliminary Class

052

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

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NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number: 13/424,054

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	13 minus 20 =	*	x 30 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*	x 125 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	530		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x		OR	x	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x		OR	x	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x		OR	x	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x		OR	x	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/424,054	03/19/2012	Chris T. Thornberry	6338.157

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

PUBLICATION NOTICE

OC00000063889186

Title: Method and System for Quick Square Roof Reporting

Publication No.US-2013-0246204-A1
Publication Date:09/19/2013

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

30589 7590 04/16/2014

DUNLAP CODDING, P.C.
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EXAMINER	
ZIMMERMAN, MATTHEW E	
ART UNIT	**PAPER NUMBER**
3684	
MAIL DATE	**DELIVERY MODE**
04/16/2014	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 13/424,054	Applicant(s) THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *09/19/2013*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-13* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-13* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.

4) ☐ Other: _____.

1. The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Status of Claims

2. Claim(s) 1-13 have been examined.

Claim Rejections - 35 USC § 101

3. 35 U.S.C. 101 reads as follows:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

4. Claims 1-13 are rejected under 35 U.S.C. 101 because the claimed invention is directed to non-statutory subject matter. The claimed invention is drawn to a computer program per se. A computer program per se is abstract instructions and not a machine or apparatus; nor is it a process as the instructions are not "acts" being performed. As such, the claimed invention is not directed to one of the four statutory categories of invention, but instead directed to nonstatutory functional descriptive material. It is noted that computer programs embodied on a computer readable medium or other structure, which would permit the functionality of the program to be realized, would be directed to a product and be within a statutory category of invention, so long as the computer readable medium is not disclosed as non-statutory subject matter per se (e.g., signals or carrier waves).

Claim Rejections - 35 USC § 102

5. The following is a quotation of the appropriate paragraphs of pre-AIA 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

6. Claims 1-13 are rejected in the alternative under pre-AIA 35 U.S.C. 102(b) as being anticipated by Como (US 2002/00897332).

Referring to Claims 1-12, Como teaches a set of instructions stored on one or more computer readable medium for running on one or more computer systems comprising instructions (*see Como Fig. 1B-1C and ¶¶0090-91*). The Examiner notes that the instructions are nowhere stated as computer executable instructions and may simply be instructions in English to perform the recited steps (ex., an instruction for identifying a geographic location of a roof may comprise "Please tell the user to write his address on a sheet of paper"). Therefore the instructions are treated as non-functional descriptive material and given little to no patentable weight.

Referring to Claim 13, Como teaches a system comprising two or more host systems, each host system having one or more computer readable medium; the first host system storing a set of instructions (*see Como Fig. 1B-1C and ¶¶0090-91*) and the second host system storing asset of instructions (*see Como Fig. 1B-1C and ¶¶0090-91*). The Examiner notes that the instructions are nowhere stated as computer executable instructions and may simply be instructions in English to perform the recited steps (ex., an instruction for identifying a geographic location of a roof may comprise

"Please tell the user to write his address on a sheet of paper"). The Examiner notes that the processors may in fact be human processors such as data entry specialists and not necessarily "computer processors." Therefore the instructions are treated as non-functional descriptive material and given little to no patentable weight.

Claim Rejections - 35 USC § 103

7. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

8. Claims 1-13 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Thornberry (US 2010/0296693) in view of Como (US 2002/0087332).

Referring to Claim 1, Thornberry teaches a set of instructions stored on one or more computer readable medium for running on one or more computer systems, comprising:

- instructions for identifying a geographic location of a roof (*see Thornberry Fig. 4A-B*);
- instructions for determining a footprint of the roof (*see Thornberry Fig. 5A-7D and ¶¶0104-112*);

- instructions for determining predominant pitch of the roof (*see Thornberry Fig. 5A-7D and ¶¶0090-98*);
- instructions for determining an estimated roofing area based on the predominant pitch and the footprint of the roof (*see Thornberry Fig. 5A-7D and ¶¶0104-112*).

Thornberry does not explicitly teach instructions for determining contact information of one or more contractors within a region of interest of the geographic location of the roof. However, Como teaches instructions for determining contact information of one or more contractors within a region of interest of a designated geographical location (*see Como ¶¶0095-96 and Fig. 12A*). It would have been obvious to one of ordinary skill in the art at the time of invention to apply the concept of determining contact information of one or more contractors in a designated geographical location to the geographical location of the roof because it would increase sales as these contractors may thus receive business from the consumer for a new roof. In addition, the results would be predictable. Specifically, Tornberry would continue to determine an estimated roofing area except that now it would also provide a list of contractors in the geographical location of the roof.

Referring to Claim 2, the combination teaches the set of instructions of claim 1, further comprising instructions for providing a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractor within the region of interest of the geographic location of the roof (*see Thornberry Fig. 5A-7D and*

¶¶0101-102; in addition, and in the alternative, the Examiner notes that the instructions are non-functional descriptive material and given little to no patentable weight).

Referring to Claim 3, the combination teaches the set of instructions of claim 2, wherein the roof report includes contact information of the customer (*see Thornberry Fig. 5A-7D, an address, claim #, order #, etc*).

Referring to Claim 4, the combination teaches the set of instructions of claim 1, wherein the one or more computer readable medium comprises a first computer readable medium of a first host system and a second computer readable medium of a second host system (*see Thornberry ¶¶0089,36, the Examiner notes that the first and second computers can be interpreted as the same computer*).

Referring to Claim 5, the combination teaches the set of instructions of claim 1, wherein instructions for identifying the geographic location of the roof further comprises instructions for obtaining contact information of a customer (*see Thornberry Fig. 4C-D*).

Referring to Claim 6, the combination teaches the set of instructions of claim 1, wherein the one or more computer readable medium further comprises instructions for receiving customer input to validate geographic location of the roof (*see Thornberry Fic. 4C-D*).

Referring to Claim 7, the combination teaches the set of instructions of claim 6, wherein the geographic location includes coordinates and validation of the geographic location includes instructions for receiving customer input to alter one or more coordinates of the geographic location (*see Thornberry Fig. 4C-D*).

Referring to Claim 8, the combination teaches the set of instructions of claim 1, wherein instructions for identifying a geographic location of the roof includes identifying one or more edges of the roof in an image (*see Thornberry Fig. 6*).

Referring to Claim 9, the combination teaches the set of instructions of claim 1, wherein instructions for determining a footprint of the roof further comprises:

- instructions for identifying edges of the roof (*see Thornberry ¶0112*);
- instructions for determining three-dimensional information of the edges including position, orientation and length using multiple oblique images from multiple cardinal directions (*see Thornberry ¶0112, ¶0029, ¶0125, ¶0100*);
- instructions for determining, automatically, one or more line segments forming a portion of a footprint of the roof utilizing position and orientation of the edges (*see Thornberry ¶0089*).

Referring to Claim 10, the combination teaches the set of instructions of claim 1, wherein determining the predominant pitch includes determining a plurality of pitch values, the predominant pitch based on the plurality of pitch values (*see Thornberry ¶0098*).

Referring to Claim 11, the combination teaches the set of instructions of claim 10, wherein each pitch value is associated with an estimated percentage of roof area to provide an average pitch value (*see Thornberry ¶0098*).

Referring to Claim 12, the combination teaches the set of instructions of claim 1, further comprising: instructions for providing the roof report to one or more contractors, the contractor located within the region of interest of the geographic location of the roof.

The Examiner notes that this is non-functional descriptive material and given little to no patentable weight.

Referring to Claim 13, Thornberry teaches a system comprising:

- two or more host systems, each host system having one or more computer readable medium the first host system storing a set of instructions that when executed by one or more processors causes the one or more processors to (*see Thornberry ¶¶0089,36*):
    - identifying a geographic location of a roof (*see Thornberry Fig. 4A-B*);
- the second host system storing a set of instructions that when executed by one or more processors causes the one or more processors to (*see Thornberry ¶¶0089,36*):
    - determining a footprint of the roof (*see Thornberry Fig. 5A-7D and ¶¶0104-112*);
    - determining predominant pitch of the roof (*see Thornberry Fig. 5A-7D and ¶¶0090-98*);
    - determining an estimated roofing area based on the predominant pitch and the footprint of the roof (*see Thornberry Fig. 5A-7D and ¶¶0104-112*).
    - provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractors within the region of interest (*see Thornberry Fig. 5A-7D*

and ¶¶0101-102; in addition, and in the alternative, the Examiner notes that the instructions are non-functional descriptive material and given little to no patentable weight).

Thornberry does not explicitly teach determining contact information of one or more contractors within a region of interest of the geographic location of the roof. However, Como teaches determining contact information of one or more contractors within a region of interest of a designated geographical location (*see Como ¶¶0095-96 and Fig. 12A*). It would have been obvious to one of ordinary skill in the art at the time of invention to apply the concept of determining contact information of one or more contractors in a designated geographical location to the geographical location of the roof because it would increase sales as these contractors may thus receive business from the consumer for a new roof. In addition, the results would be predictable. Specifically, Tornberry would continue to determine an estimated roofing area except that now it would also provide a list of contractors in the geographical location of the roof.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW ZIMMERMAN whose telephone number is (571)270-5278. The examiner can normally be reached on Mon-Fri 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jason B. Dunham can be reached on (571) 272-8109. The fax phone

number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW ZIMMERMAN/
Primary Examiner, Art Unit 3684

Notice of References Cited	Application/Control No. 13/424,054	Applicant(s)/Patent Under Reexamination THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2010/0296693	11-2010	Thornberry et al.	382/100
*	B	US-2002/0087332	07-2002	Como, Brian	705/1
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	0	"20100296693" and footprint	US-PGPUB; USPAT	OR	ON	2014/04/11 21:30
L2	2	"20100296693" and computer	US-PGPUB; USPAT	OR	ON	2014/04/11 21:45
L3	2	"20100296693" and edge	US-PGPUB; USPAT	OR	ON	2014/04/11 21:53
L4	2	"20100296693" and oblique	US-PGPUB; USPAT	OR	ON	2014/04/11 21:54
L5	2	"20100296693" and orientation	US-PGPUB; USPAT	OR	ON	2014/04/11 21:55
L6	2	"20100296693" and automatic	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 21:57
L7	2	"20100296693" and automatic$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 21:57
L8	2	"20100296693" and (seller contrator retailer merchant vendor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:01
L9	22521	705/26.1-27.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
L11	11	(thornberry near2 chris).in. (thornberry near2 dale).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
L12	45261	(image and roof)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
L13	10	11 and 12	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
L18	2	"20060200311"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:08
L19	372	(find$3 locat$3 determin$3) with (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
L20	171240	"705".clas.	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2014/04/11 22:10

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			JPO; DERWENT; IBM_TDB			
L21	108	19 and 20	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
L22	38	(find$3 locat$3 determin$3) adj2 (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
L23	7	(find$3 locat$3 determin$3) adj2 (contractor adj2 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
L24	31	(find$3 locat$3 determin$3) adj2 (contractor adj5 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
L25	17	20 and 24	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
L26	1	"20020087332" and location	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:14
L27	17755	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:24
L29	596	(estimat$3 same roof$3 same (size area footprint))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:24
L30	5	27 and 29	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
L33	99	(estimat$3 same roof$3 same (size area footprint)) and aerial	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
L34	1	27 and 33	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S6	1	13/424054	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:17
S7	10	"20100179787" "20100110074" "20100114537" "20110187713" "8078436".pn. 12/090692	US-PGPUB; USPAT	OR	ON	2014/04/10 17:33
S9	21	aerial adj roof adj estimat$4	US-PGPUB; USPAT	OR	ON	2014/04/10 17:35
S10	4	(US-20100114537-$ or US-20100179787-$ or US-20100110074-$).did. or (US-	US-PGPUB; USPAT	OR	ON	2014/04/10 17:37

Roofr Exhibit 1002, Page 92

		8078436-$).did.				
S11	23	predominant adj pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S12	0	S10 and S11	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S13	3	(predominant adj pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:38
S14	4	S10 and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:39
S15	8079	pitch near4 averag$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S16	0	S10 and S15	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S17	1	S15 and S7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S18	2	"20100114537" and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 21:51
S19	5	"8078436".pn. "8145840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S20	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S21	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515198".pn. "8401222".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:47
S22	2	"20100296693"	US-PGPUB; USPAT	OR	ON	2014/04/11 16:48
S23	2	"20100296693" and pitch	US-PGPUB; USPAT	OR	ON	2014/04/11 16:49
S24	1	"20130246204" and (pitch same averag$3)	US-PGPUB; USPAT	OR	ON	2014/04/11 16:58

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L10	6384	705/26.1-27.2.ccls.	USPAT; UPAD	OR	ON	2014/04/11 22:06
L14	3	(thornberry near2 chris).in. (thornberry near2 dale).in.	USPAT; UPAD	OR	ON	2014/04/11 22:07

Roofr Exhibit 1002, Page 93

L15	13851	(image and roof)	USPAT; UPAD	OR	ON	2014/04/11 22:07
L16	3	14 and 15	USPAT; UPAD	OR	ON	2014/04/11 22:07
L17	0	"20060200311"	USPAT; UPAD	OR	ON	2014/04/11 22:08
L28	3932	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	USPAT; UPAD	OR	ON	2014/04/11 22:24
L31	172	(estimat$3 same roof$3 same (size area footprint))	USPAT; UPAD	OR	ON	2014/04/11 22:25
L32	1	28 and 31	USPAT; UPAD	OR	ON	2014/04/11 22:25

4/ 11/ 2014 10:26:24 PM
C:\ Users\ mzimmerman1\ Documents\ EAST\ Workspaces\ 13424054.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	Art Unit
	MATTHEW ZIMMERMAN	3684

CPC- SEARCHED		
Symbol	Date	Examiner
G06Q30/0621	4/11/2014	MZ
G06Q30/0641	4/11/2014	MZ

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
705	26.1,26.5,27.1	4/11/2014	MZ

SEARCH NOTES		
Search Notes	Date	Examiner

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
705	26.1,27.1,26.5	4/11/2014	MZ

Electronically Transmitted: August 15, 2014 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No:	13/424,054	Conf. No. 7006
Inventors:	Chris T. Thornberry, Dale R. Thornberry	
Filed:	Mar. 19, 2012	
TC/A.U.:	3684	
Examiner:	ZIMMERMAN, MATTHEW E.	
Title:	Method and System for Quick Square Roof Reporting	
Docket No.:	6338.157	
Customer No.:	30589	

Mail Box Non-Fee Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE

The following is being submitted in response to the Office Action dated April 16, 2014:

Amendments to the Specification begin on page 2 of this paper.

Amendments to the Claims begin on page **3** of this paper.

Remarks/Arguments begin on page **10** of this paper.

Amendments to the Specification

Please replace paragraph [0074] with the following amended paragraph:

[0074] The footprint of the roof may be determined, in step 192. For example, the footprint of the roof may be determined using systems and methods including, but not limited to, those described in U.S. Patent Publication No. 2010/0179787, U.S. Patent Publication No. 2010/0110074, U.S. Patent Publication No. 2010/0114537, U.S. Patent Publication No. 2011/0187713, U.S. Patent No. 8,078,436, and U.S. Serial No. ~~12/090,692~~ 12/909,692, all of which are incorporated by reference herein in their entirety

Amendments to the Claims

This listing of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims:

1. (Currently Amended) ~~A set of instructions stored on one~~ One or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems that when executed cause the one or more computer systems to~~, comprising: instructions for identifying~~ identify a geographic location of a roof; ~~instructions for determining~~ determine contact information of one or more contractors within a region of interest of the geographic location of the roof; ~~and, instructions for determining~~ determine a footprint of the roof; ~~instructions for determining~~ determine predominant pitch of the roof; and ~~instructions for determining~~ determine an estimated roofing area based on the predominant pitch and the footprint of the roof.

2. (Currently Amended) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to ~~set of instructions of claim 1, further comprising instructions for providing~~ provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the

estimated roofing area and the contact information of one or more contractor within the region of interest of the geographic location of the roof.

3. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 2, wherein the roof report includes contact information of the customer.

4. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 1, wherein the one or more non-transitory computer readable medium comprises a first non-transitory computer readable medium of a first host system and a second non-transitory computer readable medium of a second host system.

5. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 1, wherein ~~instructions for~~ identifying the geographic location of the roof further comprises ~~instructions for~~ obtaining contact information of a customer.

6. (Currently Amended) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to ~~set of instructions of claim 1, wherein the one or more~~

~~computer readable medium further comprises instructions for receiving~~ receive customer input to validate geographic location of the roof.

7. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 6, wherein the geographic location includes coordinates and validation of the geographic location includes instructions for receiving customer input to alter one or more coordinates of the geographic location.

8. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 1, wherein ~~instructions for~~ identifying a geographic location of the roof includes identifying one or more edges of the roof in an image.

9. (Currently Amended) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to ~~set of instructions of claim 1, wherein instructions for determining a footprint of the roof further comprises: instructions for identifying~~ identify edges of the roof; ~~instructions for determining~~ determine three-dimensional information of the edges including position, orientation and length using multiple oblique images from multiple cardinal directions; and, ~~instructions~~

~~for determining~~ determine, automatically, one or more line segments forming a portion of a footprint of the roof utilizing position and orientation of the edges.

10. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 1, wherein determining the predominant pitch includes determining a plurality of pitch values, the predominant pitch based on the plurality of pitch values.

11. (Currently Amended) The one or more non-transitory computer readable medium ~~set of instructions~~ of claim 10, wherein each pitch value is associated with an estimated percentage of roof area to provide an average pitch value.

12. (Currently Amended) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to ~~set of instructions of claim 1, further comprising: instructions for providing~~ provide the roof report to one or more contractors, the contractor located within the region of interest of the geographic location of the roof.

13. (Currently Amended) A system, comprising:

two or more host systems, each host system having one or more non-transitory computer readable medium; the non-transitory computer readable medium of

the first host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

identify a geographic location of a roof;

determine contact information of at least one contractor within a region of interest about the geographic location of the roof;

the non-transitory computer readable medium of the second host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

determine a footprint of the roof;

determine a predominant pitch;

determine an estimated roofing area based on the predominant pitch and the footprint of the roof; and,

provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractors within the region of interest.

14. (New) A roofing estimate method, comprising:

receiving, by at least one computer processor from a user via a user terminal, a geographic location of a roof;

providing to the user, with the computer processor, imagery of the roof based on the geographic location of the roof;

providing, with the computer processor, an estimated roofing area based at least on a predominant pitch and a footprint of the roof, the footprint of the roof determined at least in part using at least one image of the roof; and

providing, with the computer processor, contact information of one or more roofing contractors within a region of interest of the geographic location of the roof.

15. (New) The roofing estimate method of claim 14, further comprising:

providing, with the computer processor, a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and the contact information of one or more contractor within the region of interest of the geographic location of the roof.

16. (New) The roofing estimate method of claim 14, wherein the footprint of the roof is determined at least in part with oblique images of the roof.

17. (New) The roofing estimate method of claim 14, wherein the predominant pitch value of the roof based at least in part on the footprint of the roof as a boundary of the roof.

18. (New) The roofing estimate method of claim 14, wherein the predominant pitch is based on a weighted average of individual pitch factors for two or more portions of the roof.

REMARKS

This is intended to be a complete response to the Office Action mailed April 16, 2014, in which claims 1- 13 are rejected. Claims 1-13 remain pending in the application and have been amended. Claims 14-18 are newly submitted claims that are believed to be generally consistent with the subject matter set forth in original claims 1-13.

In the specification, paragraph [0074] has been amended to correct a typographical error.

Based on the preceding amendments and the following remarks, Applicants respectfully request the withdrawal of the rejections and the issuance of a timely notice of allowance for claims 1- 18.

Claim Amendments

Applicants respectfully submit that the amendments to claims 1-13 and new claims 14-18 do not introduce any new matter. Written description and enablement support for the claims can be found, for example, in paragraphs [0015], [0029]-[0031], [0053], [0058], [0069], and [0074]-[0076] of the above-referenced patent application as originally filed. Therefore, no new matter is added by the amendments and the new claims.

Claim Rejection – 35 U.S.C. § 101

Claims 1-13 were rejected under 35 U.S.C. § 101 as being directed to non-statutory subject matter. The Examiner noted that computer programs embodied on a computer readable medium or other structure, which would permit the functionality of the program to be realized, would be directed to a

product and be within a statutory category of invention, so long as the computer readable medium is not disclosed as non-statutory subject matter per se (e.g., signals or carrier waves). To clarify the scope of the claims, the claims have been amended to be directed to "one or more non-transitory computer readable storage medium." The term "non-transitory computer-readable medium" comprises all types of computer-readable media, with the sole exception being a transitory, propagating signal.

In light of the foregoing, reconsideration and withdrawal of the rejection of claims 1-13 under 35 U.S.C. § 101 is respectfully requested.

Claim Rejection – 35 U.S.C. § 102(b)

Claims 1-13 were rejected under 35 U.S.C. § 102(b) as being anticipated by Como (US Patent Publication No. 2002/00897332), hereinafter "Como". For the reasons set forth below, Applicants respectfully submit that the currently pending claims are not anticipated over the cited reference.

The Examiner noted that "the instructions are nowhere stated as computer executable instructions and may simply be instructions in English to perform the recited steps" and therefore treated the instructions as "non-functional descriptive material given little to no patentable weight" (Office Action page 3). Claims 1-13 have been amended to recite "computer executable" instructions, as supported at least in paragraphs [0015], [0053], and [0058] of the application. Therefore, Applicants respectfully submit that the entirety of the claims should be given

patentable weight[1]. Como teaches a system and method for enabling a user on a network to locate contractors in at least one designated location. [See Abstract]. Como also generally refers to "[r]oofing, siding and sheet metal work." [See Paragraph [0030]] However, Como does not teach computer executable instructions for identifying a geographic location of a roof, determining a footprint of the roof, determining a predominant pitch of the roof, and determining an estimated roofing area based on the predominant pitch and the footprint of the roof, as recited in independent claims 1 and 13. Because Como does not teach each and every feature of claims 1 and 13, Como does not anticipate such claims under 35 U.S.C. §102(b).

Further, because claims 2-12 include each and every feature of independent claim 1, Como also does not anticipate claims 2-12.

In light of the foregoing, reconsideration and withdrawal of the rejection of claims 1-13 under 35 U.S.C. § 102(b) is respectfully requested.

Claim Rejection – 35 U.S.C. § 103(a)

Claims 1-13 were rejected under 35 U.S.C. § 103(a) as being unpatentable as obvious over Thornberry (US Patent Publication No. 2010/0296693), hereinafter "Thornberry", in view of Como (US Patent Publication

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[1] See MPEP §2111.05 "When determining the scope of a claim directed to a computer-readable medium containing certain programming, the examiner should first look to the relationship between the programming and the intended computer system. Where the programming performs some function with respect to the computer with which it is associated, a functional relationship will be found. For instance, a claim to computer-readable medium programmed with attribute data objects that perform the function of facilitating retrieval, addition, and removal of information in the intended computer system, establishes a functional relationship such that the claimed attribute data objects are given patentable weight. See *Lowry*, 32 F.3d at 1583-84, 32 USPQ2d at 1035.

No. 2002/00897332), hereinafter "Como". Applicants respectfully submit that the currently pending claims are not made obvious by the cited references.

For example, Thornberry does not disclose, teach, or even suggest, determining a predominant pitch, or determining an estimated roofing area based on the predominant pitch and the footprint of the roof, as recited in part in independent claims 1 and 13. The Examiner cites to Thornberry Figs. 5A-7D and paragraphs [0090]-[0098] as disclosing instructions for determining predominant pitch of the roof. However, these sections of Thornberry disclose determining "pitch direction," also described as "vector direction corresponding to roof pitch" (see paragraphs [0089]-[0090] and FIG. 5E), not "predominant pitch."

Examples of pitch direction vectors are shown in FIG. 5E as arrows "pointing in the downward direction, corresponding to the direction of rain flow" (paragraph [0089]). Thornberry describes an example of computer programming to determine pitch direction in paragraphs [0090]-[0098]. For example, see paragraph [0092] describing determining pitch direction for a section of roof running from a single ridge line parallel to a perimeter line – where pitch direction "runs from the ridge towards the perimeter." Also see paragraph [0097]-[0098] describing finding pitch direction "for completely enclosed shapes where all sides are valleys at the intersection of multiple planes" by taking an average slope and averaging the slope direction of the planes whose pitch runs into the plane in question and then using "that direction as the pitch direction for the plane." Therefore, Thornberry discloses how to determine "pitch direction," not "predominant pitch."

The Examiner cites to Thornberry Figs. 5A-7D and paragraphs [0104]-[0112] as disclosing "determining an estimated roofing area based on the predominant pitch and the footprint of the roof." However, as previously discussed, Thornberry does not determine predominant pitch, and therefore cannot determine an estimated roofing area based on predominant pitch and footprint of the roof. Nowhere does Thornberry disclose using predominant pitch to calculate area.

Additionally, because dependent claims 2-12 include each and every feature of independent claim 1, Thornberry also does not render claims 2-12 obvious under 35 U.S.C. §103(a).

Further, Applicants respectfully submit that the Como reference does not supply the deficiencies of Thornberry, for the reasons set forth above. The arguments and comments concerning Como will not be reiterated herein, but such are deemed relevant to the Examiner's rejection of claims 1-13 and are therefore incorporated herein by reference.

In light of the foregoing, reconsideration and withdrawal of the rejection of claims 1-13 under 35 U.S.C. § 103(a) is respectfully requested.

CONCLUSION

The foregoing is intended to be a complete response to the Office Action dated April 16, 2014. Applicants respectfully request reconsideration and withdrawal of the rejections set forth in the Office Action and a timely notice of allowance for all of the pending claims 1-18. Should the Examiner have any questions or comments regarding the foregoing, or any other matter, the undersigned would welcome a telephonic interview with the Examiner.

Respectfully Submitted,



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Attorney for Applicants

Electronic Patent Application Fee Transmittal

Application Number:	13424054
Filing Date:	19-Mar-2012
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Marc Alan Brockhaus/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 1 month with $0 paid	2251	1	100	100

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	100

Electronic Acknowledgement Receipt

EFS ID:	19880842
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Marc Alan Brockhaus/Lori Radford
Filer Authorized By:	Marc Alan Brockhaus
Attorney Docket Number:	6338.157
Receipt Date:	15-AUG-2014
Filing Date:	19-MAR-2012
Time Stamp:	16:22:11
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$100
RAM confirmation Number	2441
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	6338157_Transmittal08152014.pdf	65950 [illegible]	no	1
Warnings:					
Information:					
2	Extension of Time	6338157_Extension08152014.pdf	62085 [illegible]	no	1
Warnings:					
Information:					
3		6338157_Response08152014.pdf	441924 [illegible]	yes	15

Multipart Description/PDF files in .zip description

Document Description	Start	End
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Claims	2	9
Abstract	10	15

Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30357 [illegible]	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	600316		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/21 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission	

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew E. Zimmerman
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☑ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☑ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please identify below):
  See Remarks

Remarks

ELECTRONICALLY TRANSMITTED:
1. SB21 Transmittal Form (1 pg);
2. SB22 Extension of Time (1 pg); and
3. Response (15 pgs).

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	DUNLAP CODDING, P.C.		
Signature	Marc Brockhaus		
Printed name	Marc A. Brockhaus		
Date	08/15/2014	Reg. No.	40,923

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Marc Brockhaus		
Typed or printed name	Marc A. Brockhaus	Date	08/15/2014

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/22 (03-13)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)

Docket Number (Optional): 6338.157

Application Number: 13/424,054

Filed: 03/19/2012

For: Chris T. Thornberry

Art Unit: 3684

Examiner: Matthew E. Zimmerman

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

		Fee	Small Entity Fee	Micro Entity Fee	
☑	One month (37 CFR 1.17(a)(1))	$200	$100	$50	$ 100.00
☐	Two months (37 CFR 1.17(a)(2))	$600	$300	$150	$
☐	Three months (37 CFR 1.17(a)(3))	$1,400	$700	$350	$
☐	Four months (37 CFR 1.17(a)(4))	$2,200	$1,100	$550	$
☐	Five months (37 CFR 1.17(a)(5))	$3,000	$1,500	$750	$

☑ Applicant asserts small entity status. See 37 CFR 1.27.

☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.

☐ A check in the amount of the fee is enclosed.

☑ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number _____.

☑ Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant.

☑ attorney or agent of record. Registration number 40,923.

☐ attorney or agent acting under 37 CFR 1.34. Registration number _____.

Marc Brockhaus — Signature

08/15/2014 — Date

Marc A. Brockhaus — Typed or printed name

405-607-8600 — Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

☐ * Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

PTO/SB/06 (09-11)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/424,054	Filing Date 03/19/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 = *		X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 = *		X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	08/15/2014	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 18	Minus	** 20	= 0	X $40 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/Davina Butler/

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ELECTRONICALLY FILED ON: October 20, 2014

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

Substitute for form PTO/SB/08a

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	ZIMMERMAN, MATTHEW E.
Attorney Docket Number	6338.157

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H04N 7/18, 9/47, 5/225, G03B 17/24, G01V 1/00, G01W 1/10, G06F 17/00, G06G 7/48

A1

(11) International Publication Number: **WO 99/18732**

(43) International Publication Date: 15 April 1999 (15.04.99)

(21) International Application Number: PCT/US98/20809

(22) International Filing Date: 5 October 1998 (05.10.98)

(30) Priority Data:
08/944,887 6 October 1997 (06.10.97) US

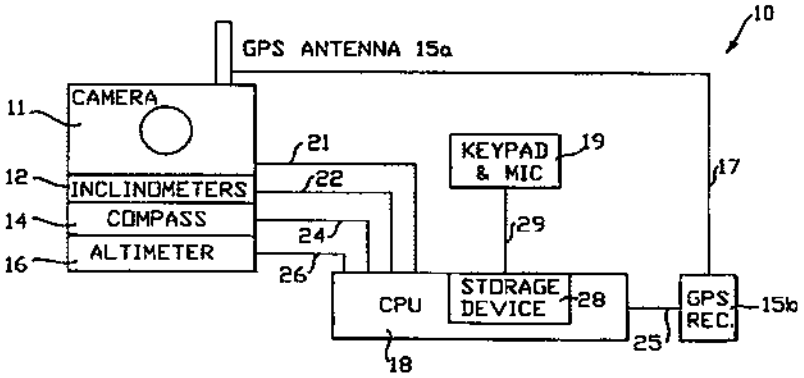
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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: DIGITAL-IMAGE MAPPING



(57) Abstract

In accordance with the present invention, there is provided an image capture and georeferencing unit. The unit comprises in combination, a portable camera (11) with a GPS antenna and receiver (15b) that captures global coordinates, a compass (14) for determining the direction and an inclinometer (12) for the photographic angle. The camera and other instruments feed image and shot data to a CPU (18), where the shot data is analyzed, mathematically interpolated and reconciled with known constants. The image and shot data are stored in memory (28). The "shot data" analyzed by the computer includes camera parameters such as camera: location, latitude, longitude and altitude, time, bearing, depression angle/pitch or azimuth, roll and yaw. The portable camera and data-gathering instruments move together and, therefore, function as a single unit that provides precise, accurate data and digitized photographic image information, despite topographical changes and/or altitude variations of the camera. Exact digital representations with precise coordinates are instantly available for precise reconnaissance purposes. The photographic shot data is mathematically adjusted (trigonometrically) to coordinate the points on the ground plane with the points in the image plane in order to produce an automatically computationally georeferenced digital image. Elevation data may be used to corroborate or enhance the accuracy of the trigonometric interpolations.

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DIGITAL-IMAGE MAPPING

FIELD OF THE INVENTION

The present invention pertains to the capture and automatic georeferencing of a camera and/or images captured by the camera by utilizing a portable camera and data unit and, more particularly, to a system and method of obtaining precisely located, oblique, digitized land images, taking into account diverse topography and varying camera angles, including changes in heading, roll and yaw.

BACKGROUND OF THE INVENTION

Aerial photography of land images for reconnaissance purposes is well known, as illustrated in United States Patent No. 5,247,356 (issued to John A. Ciampa on September 21, 1993), entitled METHOD AND APPARATUS FOR MAPPING AND MEASURING LAND. This patent teaches that coordinates of a land location can be calculated and combined with photographic information about the terrain. The global position and the elevation information are converted into digitized form, along with the image information and then stored in computer memory.

One of the problems of such aerial-photography methodology is that photographs must be taken over landscapes of relatively flat terrain, while a plane's altitude is generally parallel with the landscape, or at aircraft altitudes where topographical variations are generally minimized in the angular calculations. The inability of the prior art of aerial photographic systems to coordinate image information with collateral measurements has often required the use of expensive

flight platforms, preordained flight paths and orthogonal camera angles.

In order to obtain exact geographic coordinates of any land image, it is no longer necessary to stabilize the camera, flight path and elevation, as previously calculated in the aforementioned patent. Due to additional data and calculations, the camera may now be freed up, regardless of topographical changes and changes of camera angles with respect to this changing topography.

The present invention combines into a single unit a portable camera with a data unit containing a Global Position Satellite (GPS) antenna/receiver, including but not limited to differential GPS or other type GPS system, a compass and inclinometer. The data unit provides camera coordinates and triaxial angle data, which are combined with the digital representations of the photographic image. Trigonometric formulas correlate to the image pixel and corresponding ground coordinates. An iterative algorithm, as is well known in fuzzy logic and optimization routines, is used to compensate for the changes and variations in the landscape topography. This is accomplished by using known Digital Elevation Models (DEM) that are furnished by the United States Geophysical Survey (USGS) or other digital terrain models captured as a result of laser signals. In addition the system's mathematical algorithms take account of the differences in measurements of known objects such as cars and distribute these differences to fixed variables which has the effect of raising, lowering, tilting or reshaping a virtual ground plane that compensates for differences caused by elevation. The particular camera to be utilized with this invention may be an analog, digital video or still digital

camera. The camera may be carried by an operator who is on foot or in a land, sea or air craft.

The inclinometer, the GPS antenna/receiver and a compass are affixed to the camera so that they move together as a unit. The inclinometer detect changes in the depression angle and the roll angles of the camera. The photographic data is attached to the image file and is transferred to a small microprocessor (CPU), where the storage device can be a PCMCIA memory card. The microprocessor processes and links the shot data from the instruments with a digital image file. All of the data regarding depression angle, global position, heading (or bearing) and image are interpolated and combined with the shot time. This digitized image and other information are then stored in a spatially managed image file mosaic software, whereby images can be retrieved based on their map location or from a gallery or "contact sheet" of digital miniature thumbnails.

The method of the invention comprises the following steps. The image is first digitally captured by a "digital" camera or other digitizing device, along with the aforementioned shot data. "Shot data" is then analyzed by the computer, including location (i.e., latitude, longitude and altitude); camera bearing or heading (the compass direction in which the lens is pointing); the camera depression angle or azimuth; and the camera roll (i.e., the yaw of the camera, with respect to its horizontal axis). The shot data is then mathematically adjusted (trigonometrically) to coordinate the points on the ground plane with the points in the image plane, so as to produce an automatically computationally georeferenced digital image. Elevation data may be used to corroborate or enhance the accuracy of the trigonometric interpolation. The result of all of this

processing provides an image, or a portion thereof, from which can be obtained geographic coordinates of any point on the ground and/or ground measurements taken between any two points in the image. This "georeferencing" of each image also determines its placement in a series of adjacent images, so that each image can be depicted as a "tile" within a "mosaic" of tiled images. Each image, in addition to its georeference, is processed so as to contain a discrete sequential identifier, the date and the time. Many images of the same landscape may be taken by using different angles and camera positions, each of which is accessible by means of a graphical user interface. Trigonometric processing also takes into account fixed variables, such as lens focal length, the size of the image plane, the number of pixels in the X-Y axes (horizontal and vertical planes) and the size of the pixels.

It is the object of the present invention to provide an improved oblique aerial-photography system so that any person without special "photo-interpreting" skills may conduct electronic field studies of land and building, as well as ground-based visual inventories.

It is another object of this invention to provide a portable photography system that combines into a single operational unit a photographic camera with a GPS antenna/receiver that captures global coordinates, a compass for determining camera direction and inclinometer for calculating the photographic angle.

It is a further object of this invention to provide a digital photographic imaging system that "georeferences" each geographical image, so that each image, or part thereof, can be depicted as a "tile" within a "mosaic" of tiled images.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided an image capture and georeferencing unit. The unit comprises in combination, a portable camera with a Global Position Satellite (GPS) antenna/receiver that captures global coordinates, a compass for determining the direction and an inclinometer for calculating the photographic angle. The camera and other instruments feed image and shot data to a CPU, where the shot data is analyzed, mathematically interpolated and reconciled with known constants. The image and shot data are then stored in memory. The "shot data" analyzed by the computer includes camera location (i.e., latitude, longitude and altitude), time, camera bearing (the compass direction in which the lens is pointing), the camera depression or azimuth, and camera roll (i.e., the yaw of the camera with respect to its horizontal axis). The portable camera and data-gathering instruments move together and, therefore, function as a single unit that provides precise, accurate data and digitized photographic image information, despite topographical changes and/or altitude variations of the camera. They also provide precise data on the GPS location of the camera and its altitude with respect to the ground. Exact digital representations with precise coordinates are instantly available for precise reconnaissance purposes. The photographic shot data is mathematically adjusted (trigonometrically) to coordinate the points on the ground plane with the points in the image plane in order to produce an automatically computationally georeferenced digital image. Elevation data may be used to corroborate or enhance the accuracy of the trigonometric interpolations.

The result of all of this processing provides an image,

or a portion thereof, from which can be obtained geographic coordinates of any point on the ground and/or measurements on the ground taken between any two points in the image. The "georeferencing" of each image also determines its placement in a series of adjacent images, so that each image can be depicted as a "tile" within a "mosaic" of tiled images. Each image, in addition to its georeference, is processed so as to contain a discrete sequential identifier, the date and the time. Many images of the same landscape may be taken by using different angles and camera positions, each of which is accessible by means of a graphical user interface. Processing adjusts the shot data to compensate for fixed camera data, such as the lens focal length, the size of the image plane, the number of pixels in the X-Y axes (horizontal and vertical planes) and the size of the pixels.

BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when considered in conjunction with the subsequent detailed description, in which:

FIGURE 1 illustrates a schematic, block diagram of the camera and instruments of this invention;

FIGURE 2 depicts a flow diagram of the processing method used in the system shown in FIGURE 1, in which an image is captured, digitized and combined with shot data and other georeferencing information, and thereafter stored for future use;

FIGURE 3 shows a flow diagram of the image file management software of the inventive system depicted in FIGURE

1; and

FIGURES 4 A-C illustrate the inventive technique used to mathematically calculate the georeference at each pixel of the image; and

FIGURES 5 A-B illustrate a schematic view of the inventive technique used to mathematically reconcile the shot data with Digital Elevation Models and/or other known "ground truth".

DESCRIPTION OF THE PREFERRED EMBODIMENT

Generally speaking, the invention features an imaging system, including a novel combination of a portable camera, GPS receiver, bearing compass and inclinometer(s). All of the components move and function as a single unit, so that, despite changes in the depression and the roll angles of the camera, each digital image is captured, along with shot data, which becomes automatically, computationally georeferenced.

Now referring to FIGURE 1, an imaging system 10 of this invention is illustrated. The system combines a camera 11 with an inclinometer 12, a compass 14, an optional altimeter 16 and a Global Position Satellite (GPS) antenna/receiver, 15a and 15b, respectively. The particular camera 11 that can be utilized with this invention may be a databack film camera that is capable of affixing shot time and subsequent digitization. The camera 11 can also be an analog, a digital video or a still digital camera. The camera 11, inclinometer 12, compass 14, optional altimeter 16 and GPS receiver 15b are each individually connected to a CPU processor 18 containing a fixed or removable memory 28 (such as a PCMCIA card) via respective lines 21, 22, 24, 26 and 25. The

GPS antenna 15a is connected to the GPS receiver 15b via line 17. Also connected to the CPU processor 18 are an optional key-pad-and microphone 19 via line 29. The key-pad-and-microphone 19 can be used to enter comments or additional information with respect to the photographed site. Where altitude provided by the GPS is adequate, the altimeter 16 may be dispensed with. Where comments are impractical, the key-pad-and-microphone 19 may also be dispensed with.

The invention reflects the discovery that in addition to camera location, it is necessary to factor into the calculations the changes in the elevation of the depicted land, the depression and the bearing of the camera, with respect to this encompassed land. The compass 14 provides camera heading or bearing information; the GPS antenna/receiver 15a and 15b provide the camera position information (latitude, longitude and altitude); the inclinometers 12 provide the depression and roll angles; and the optional altimeter laser or other 16 provides additional altitude information. As an alternative to or in addition to instrumental measurements of land, the system may computationally deduce elevations within the image by assessing deficiencies in measurements of known objects such as cars. These variables are combined with the digital image, plane measurements, focal length, and pixel data to give a georeferenced image down to the pixel level.

The instrument's shot data are recorded and used to coordinate the points on the ground plane with the points in the image plane in order to produce a georeference for each pixel. DEM data are used to corroborate or enhance the accuracy of the trigonometric interpolations. The result of all of this processing provides an image, or a portion thereof, from which

can be obtained geographic coordinates of any point on the ground and/or measurements on the ground taken between any two points in the image. The "georeferencing" of each image also determines its placement in a series of adjacent images, so that each image can be depicted as a "tile" within a "mosaic" of tiled images. Each image, in addition to its georeference, is processed so as to contain a discrete sequential identifier, the date and the time. Many images of the same landscape may be taken by using different angles and camera positions, each of which is accessible by means of a graphical user interface. Processing adjusts the shot data to compensate for the lens focal length, the size of the image plane, the number of pixels in the X-Y axes (horizontal and vertical plans) and the size of the pixels.

The GPS antenna/receiver 15a and 15b can be obtained from, among others, Trimble Navigation Systems of Sunnyvale, California. A fluxgate compass 14 and inclinometers 12 are available from, among others, KVH Industries, Inc., of Middletown, Rhode Island.

In processing the information, the CPU 18 accesses Digital Elevation Model (DEM) data from a database in order to adjust the image data for topographical variations. The position variables (camera X, Y and Z coordinates) are obtained from the Global Position Satellite (GPS) receiver. The pointing variables (camera heading or bearing) are obtained from the compass 14, and the depression and the roll information are obtained from the inclinometers 12.

The processing assumes a simple, pin-hole camera model. The ground position of the photographed image can be defined by simple triangular, trigonometric processing of the depression

angle ϕ_D, the size of the image plane and the focal length (FL) of the camera as shown in FIGURE 4A. A pixel location (P_x, P_y) of a particular point selected on a displayed image can be processed for a particular depression angle by calculating the inverse tangent of the angle as shown in FIGURE 4B.

Referring to FIGURE 4C, assuming a northerly direction, the angle ϕ_D (depression angle) is offset by the arctangent (film height [y] * (row containing focal axis [F_y] -row of selected pixel [P_y])/2* image plane height [Z] * focal length [FL]) resulting in angle ϕ_p. The angle ϕ_p is subtracted from the recorded depression angle ϕ_p and denoted as ρ_v relative to the point on the ground immediately below the camera, with camera altitude above the ground "Z" (height). The northerly distance to the selected point [P_x, P_y] is Z* sin ($\pi/_2$ - ρ_v). The east-west distance is calculated from the (column of selected pixel [P_x] -focal axis column [F_x]/$_2$)*film width [x]/image plane width [x_1].

east-west distance = Camera Z*cos ϕ/2*focal length * sin ρ_v

When the direction is other than north, a simple rotation is made on the point to establish the ground location. The true location is then obtained by translating the ground location of the camera into its recorded position.

Ground location for terrain "T" that is not flat is adjusted by using DEM data and an iterative algorithm, well known in the art of optimization routines. The processor 18 uses the algorithm and the point [g_1] assumed for a flat terrain as shown in FIGURE 5A. The processor accesses the DEM data for that point and obtains the elevation [g_2] as shown in FIGURE 5B. The process is complete if the elevation at that camera location is

the same as that of the selected point. Otherwise, the camera elevation is modified to account for the difference in the ground elevation of the selected point. The revised value is then used to estimate the ground location (G_3). The iterative algorithm continues to revise the estimate until it converges to within acceptable limits. The algorithm is modified to adjust for roll of the camera by transforming pixel coordinates to a new set of coordinates. The transformation is a simple rotation about focal axis "F" by well-known mathematical methods.

$$T\mu = [\cos \mu \ \sin \mu \ ] \ - \ \sin\mu \ \cos \mu$$

The data points provided by the DEM are sampled along the ground every 30 meters in an orthogonal grid bounded by g_2 and g_1, as shown. Intermediate points are obtained by interpolation, such as by using bilinear interpolation or bicubic splines.

The position of the camera and the pointing angles are subject to a small degree of error and, therefore, may be reconciled with measured ground truth other than DEM data. This is accomplished by locating or measuring discrete objects in several images and then modifying the collected data so as to obtain more accurate estimates.

Referring to FIGURE 2, a flow chart 100 is illustrated for the image-and-data-capture process of this invention. An image is captured by camera 12, step 101; the image information is converted to digital form, step 102. The camera altitude, ground location, tilt, depression angle and heading (bearing) are then obtained, as shown in step 103. The information from steps 102 and 103 is then combined, step 104. The data is then adjusted according to focal length, pixel size, pixel location

and focal axis, as previously explained with reference to FIGURE 4, step 105. The result of all of the processing provides an image, or a portion thereof, from which can be obtained geographic coordinates on the ground and/or ground measurements taken between any two image points. The "georeferencing" of each image determines its placement in a series of adjacent images, so that each image can be depicted as a "tile" within a "mosaic" of tiles images, step 106. The DEM data is then used to adjust the image data for variations in the terrain, step 107. The image data is then compressed for storage purposes, step 108.

Referring to FIGURE 3, a flow chart 200 illustrates in more detail the DEM adjustment process for the data obtained in FIGURE 2. A tile from the mosaic is obtained, steps 201 and 202. In conjunction with the selection, an associated DEM elevation file is accessed, step 203. The accessed data is then combined and the digitized data decompressed, step 204. The image and adjoining images are then displayed, step 206. Certain features of the images are selected, step 207, and the horizontal or vertical measurements are selected for review, step 208. Different images are reviewed, step 210, and the end points are measured, step 209. The ground points are then estimated, step 211, and compared with the DEM data, step 212. If the elevation estimate is different, the elevation is revised, step 214, and entered via line 215. A new estimate is made via return loop 205, and the re-entering of step 211. After a few iterations, the decision is made, step 212, to report distance between points, step 217 via line 216. When the estimate is found accurate, the actual distance between the selected ground points is made, step 217. The process is then repeated via return loop 220, in order to obtain the distance values for other selected

points and tiles.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

What is claimed is:

1. An image georeferencing system, comprising:

a portable, data-capturing device affixed to a camera, with said camera providing an image, said portable, data-capturing device and said camera being carried by hand or upon an aerial surveillance vehicle or other craft, said portable, data-capturing device providing data for computationally generating a georeference, and being independently operative of any aeronautical instruments, said portable, data-capturing device further including at least one inclinometer for determining depression angle, a means for determining heading or bearing of said data-capturing device and a global position satellite antenna/receiver for obtaining georeferencing information, said at least one inclinometer and said global position satellite antenna/receiver being movable as a single unit; and

a processor operatively connected to said portable, data-capturing device and said camera, said processor comprising data storage means, including digital elevation information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said data-capturing device, said processor computationally generating a georeference of any object within said image, in which said object can be located and measured therewithin.

2. The imaging georeferencing system in accordance with claim 1, further comprising an altimeter connected to said processor for determining additional altitude data of said portable, data-capturing device.

3. The imaging georeferencing system in accordance with claim 1, further comprising a key pad connected to said processor for entering pilot information into said processor.

4. The imaging georeferencing system in accordance with claim 1, further comprising a microphone connected to said processor for entering comments into said processor.

5. An image georeferencing system, comprising:

a camera for providing an image in combination with a georeferencing, data-capturing device and inclinometer, said combination carried by hand or upon an aerial surveillance vehicle or other craft, said georeferencing, data-capturing device capturing data for computationally generating a georeference of any object within said image; and

a processor connected to said camera and georeferencing, data-capturing device combination, said processor comprising data storage means, including digital elevation information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said data-capturing device and processing said captured data for computing a georeference of any object within said image.

6. The image georeferencing system in accordance with claim 5, wherein said camera and georeferencing, data-capturing device combination comprises at least one inclinometer for determining depression angle, a means for determining heading of said image and a global position satellite antenna/receiver for obtaining georeferencing information with respect to said image, said at least one inclinometer and said global position satellite

antenna/receiver being movable as a single unit, with each being connected to said processor.

7. The image georeferencing system in accordance with claim 6, further comprising an altimeter connected to said processor for determining additional altitude data.

8. The image georeferencing system in accordance with claim 5, further comprising a key pad connected to said processor for entering comments into said processor.

9. The image georeferencing system in accordance with claim 5, further comprising a microphone connected to said processor for entering comments into said processor.

10. A method of computationally georeferencing images, comprising the steps of:

a) capturing an image of terrain to provide digitized image information;

b) combining said digitized image information with shot data from instrumental data and camera data;

c) analyzing said combined digitized image and said shot data;

d) obtaining information with respect to image location data, including at least one of a group of location data including variations in camera latitude, longitude, altitude, camera bearing, camera depression angle, roll and yaw; and

e) adjusting information obtained in step (b) and utilizing information obtained in step (d) to coordinate points on a ground plane with points in an image plane to produce

a georeferenced digital image of the terrain.

11. The method in accordance with claim 10, further comprising the step of:

f) utilizing digital elevation model data to enhance accuracy of image and georeferencing information obtained in step (b).

12. The method in accordance with claim 10, further comprising the step of:

f) processing said information obtained in step (b) to provide an image, or a portion thereof, that can be spatially located by using geographic coordinates and/or measurements taken between any two points.

13. The method in accordance with claim 10, further comprising the step of:

f) depicting combined image information and georeferencing information as a "tile" within a "mosaic" of tiled images, with each image, in addition to its respective georeference, being processed so as to contain a discrete sequential identifier, date and time.

14. The method in accordance with claim 10, further comprising the step of:

f) capturing a multiplicity of images of the same terrain in accordance with step (a) by using different angles and capture positions to provide different points of view of the same scene, each of which being accessible by means of a graphical user interface.

15. The method in accordance with claim 10, further comprising the steps of:

f) obtaining information with respect to lens focal length, size of image plane, number of pixels in horizontal and vertical planes, and size of pixels; and

g) processing said image information in step (a) with respect to said information obtained in step (f) to adjust said image information.

16. A method of aerial surveillance of terrain, comprising the steps of:

f) aerially capturing an image of terrain to provide image information;

g) combining said image information with shot data as georeferencing variables;

h) analyzing said combined image and said georeferencing variables;

i) obtaining information with respect to image location data, including at least one of a group of location data including variations in camera latitude, longitude, altitude, camera bearing, camera depression angle, roll and yaw; and

j) adjusting information obtained in step (b) and utilizing information obtained in step (d) to coordinate points on a ground plane with points in an image plane to produce an exact image of the terrain.

17. The method in accordance with claim 16, further comprising the step of:

f) utilizing digital elevation model data to enhance accuracy of image and georeferencing information obtained in step (b).

18. The method in accordance with claim 16, further comprising the step of:

f) processing said information obtained in step (b) to provide an image, or a portion thereof, that can be spatially located by using geographic coordinates and/or make known geographic coordinates of the ground at any point depicted in the image and/or ground measurements taken between any two points of the image.

19. The method in accordance with claim 16, further comprising the step of:

f) depicting combined image information and georeferencing information as a "tile" within a "mosaic" of tiled images, with each image, in addition to its respective georeference, being processed so as to contain a discrete sequential identifier, date and time.

20. The method in accordance with claim 16, further comprising the step of:

f) taking a multiplicity of images of the terrain in accordance with step (a) by using different angles and capture positions to provide multiple views, accessible by means of a window-like, graphical user interface.

21. The method in accordance with claim 16, further comprising the steps of:

f) obtaining information with respect to lens focal length, size of image plane, number of pixels in horizontal and vertical planes, and size of pixels; and

g) processing said image information obtained in step (a) with respect to said information obtained in step (f) to adjust said image information.

22. An image georeferencing system comprising

a camera for providing an image in combination with a georeferencing, data-capturing device, said combination carried by hand or upon an aerial surveillance vehicle or other craft, said georeferencing, data-capturing device capturing data for computationally generating and recording a georeference of the camera for each captured image; and further comprising a device selected from the group consisting of an inclinometer, means for determining heading or bearing of the camera.

23. The image georeferencing system of claim 22 further comprising a processor connected to said camera and georeferencing, data-capturing device combination, said processor comprising data storage means, including digital elevation information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said data-capturing device and processing said captured data for computing a georeference of any object within said image.

24. The image georeferencing system of claim 23 wherein said camera further comprising means for recording the depression and roll angle of the camera for each image captured by the camera.

25. The image georeferencing system of claim 23 wherein said camera further comprising means for recording the altitude of the camera for each image captured by the camera.

26. The image georeferencing system of claim 23 wherein said georeference data is obtained by a global position system antenna and receiver connected to the processing unit.

27. The image georeferencing system of claim 26 wherein said processing unit is within said camera.

28. The image georeferencing system of claim 24 wherein said angle means is an inclinometer connected to the processing unit.

29. The image georeferencing system of claim 25 wherein said altitude means is an altimeter connected to the processing unit.

30. A digital mapping system, comprising:

a portable data-capturing device affixed to a camera, said camera providing an image, said portable data-capturing device and said camera being carried by hand or upon an aerial surveillance vehicle or other craft for providing a pixel-based image, said portable data-capturing device providing data for computationally generating a georeference for each pixel of said pixel-based image, said data-capturing device being independently operative of any aeronautical instruments, said portable data-capturing device further including at least one inclinometer for determining declination angel, a means for determining heading or bearing of said image-capturing device and a global position satellite antenna/receiver for obtaining georeferencing information, said at least one inclinometer and

said global position satellite antenna/receiver being movable as a single unit; and

a processor operatively connected to said portable data-capturing device and said camera, said processor comprising data storage means, including digital elevation information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said data-capturing device, said processor computationally generating a georeference of each pixel and any object within said image, wherein said object can be located and measured within said image.

31. The imaging georeferencing system in accordance with claim 30, further comprising a key pad connected to said processor for entering pilot information into said processor.

32. The imaging georeferencing system in accordance with claim 30, further comprising a microphone connected to said processor for entering comments into said processor.

33. An image georeferencing system in accordance with claim 30, further comprising:

a camera for providing an image in combination with a georeferencing, data-capturing device and inclinometer, said combination carried by hand or upon an aerial surveillance vehicle or other craft, said georeferencing, data-capturing device capturing data for computationally generating a georeference of any object within said image; and

a processor connected to said camera and georeferencing, data-capturing device combination, said processor comprising data storage means, including digital elevation

information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said data-capturing device and processing said captured data for computing a georeference of any object within said image.

34. A digital mapping system, comprising:

a camera for providing a pixel-based image in combination with a georeferencing data-capturing device, said combination carried by hand or upon an aerial surveillance vehicle or other craft, said georeferencing data-capturing device capturing data for computationally generating a georeference of each pixel and any object within said image; and

a processor connected to said camera and georeferencing data-capturing device combination, said processor comprising data storage means, including digital elevation information and a program for modifying image and georeferencing information with respect to variations in terrain and changes in heading, roll and yaw of said image-capturing device, and processing said captured data for computing a georeference of each pixel and any object within said image.

35. The image georeferencing system in accordance with claim 34, wherein said camera and georeferencing, data-capturing device combination comprises at least one inclinometer for determining depression angle, a means for determining heading of said image and a global position satellite antenna/receiver for obtaining georeferencing information with respect to said image, said at least one inclinometer and said global position satellite antenna/receiver being movable as a single unit, with each being connected to said processor.

36. The image georeferencing system in accordance with claim 35, further comprising an altimeter connected to said processor for determining additional altitude data.

37. The image georeferencing system in accordance with claim 34, further comprising a key pad connected to said processor for entering comments into said processor.

38. The image georeferencing system in accordance with claim 34, further comprising a microphone connected to said processor for entering comments into said processor.

39. A method of digitally mapping terrain, comprising the steps of:

a) capturing a pixel-based image of terrain to provide digitized image information;

b) capturing georeferencing information;

c) combining said digitized image information with said captured georeferencing information; and

d) processing said combined digitized image information and said captured georeferencing information in order to generate a georeference of each pixel and any object within said image of said terrain, whereby said object can be located within said image of terrain.

40. The method in accordance with claim 39, further comprising the step of:

f) utilizing digital elevation model data to enhance accuracy of image and georeferencing information obtained in step (b).

41. The method in accordance with claim 39, further comprising the step of:

f) processing said information obtained in step (b) to provide an image, or a portion thereof, that can be spatially located by using geographic coordinates and/or measurements taken between any two points.

42. The method in accordance with claim 39, further comprising the step of:

f) depicting combined image information and georeferencing information as a "tile" within a "mosaic" of tiled images, with each image, in addition to its respective georeference, being processed so as to contain a discrete sequential identifier, date and time.

43. The method in accordance with claim 39, further comprising the step of:

f) capturing a multiplicity of images of the same terrain in accordance with step (a) by using different angles and capture positions to provide different points of view of the same scene, each of which being accessible by means of a graphical user interface.

44. The method in accordance with claim 39, further comprising the steps of:

f) obtaining information with respect to lens focal length, size of image plane, number of pixels in horizontal and vertical planes, and size of pixels; and

g) processing said image information in step (a)

with respect to said information obtained in step (f) to adjust said image information.

45. A method of aerial surveillance of terrain, comprising the steps of:

a) aerially capturing a[n] pixel-based image of terrain to provide image information;

b) combining said image information with georeferencing information; and

c) processing said combined image and said georeferencing information, in order to generate a georeference of each pixel and any object within said image of terrain, whereby said object can be located within said image of terrain.

46. The method in accordance with claim 45, further comprising the step of:

f) utilizing digital elevation model data to enhance accuracy of image and georeferencing information obtained in step (b).

47. The method in accordance with claim 45, further comprising the step of:

f) processing said information obtained in step (b) to provide an image, or a portion thereof, that can be spatially located by using geographic coordinates and/or make known geographic coordinates of the ground at any point depicted in the image and/or ground measurements taken between any two points of the image.

48. The method in accordance with claim 45, further

comprising the step of:

f) depicting combined image information and georeferencing information as a "tile" within a "mosaic" of tiled images, with each image, in addition to its respective georeference, being processed so as to contain a discrete sequential identifier, date and time.

49. The method in accordance with claim 45, further comprising the step of:

f) taking a multiplicity of images of the terrain in accordance with step (a) by using different angles and capture positions to provide multiple views, accessible by means of a window-like, graphical user interface.

50. The method in accordance with claim 45, further comprising the steps of:

f) obtaining information with respect to lens focal length, size of image plane, number of pixels in horizontal and vertical planes, and size of pixels; and

g) processing said image information obtained in step (a) with respect to said information obtained in step (f) to adjust said image information.

Roofr Exhibit 1002, Page 157

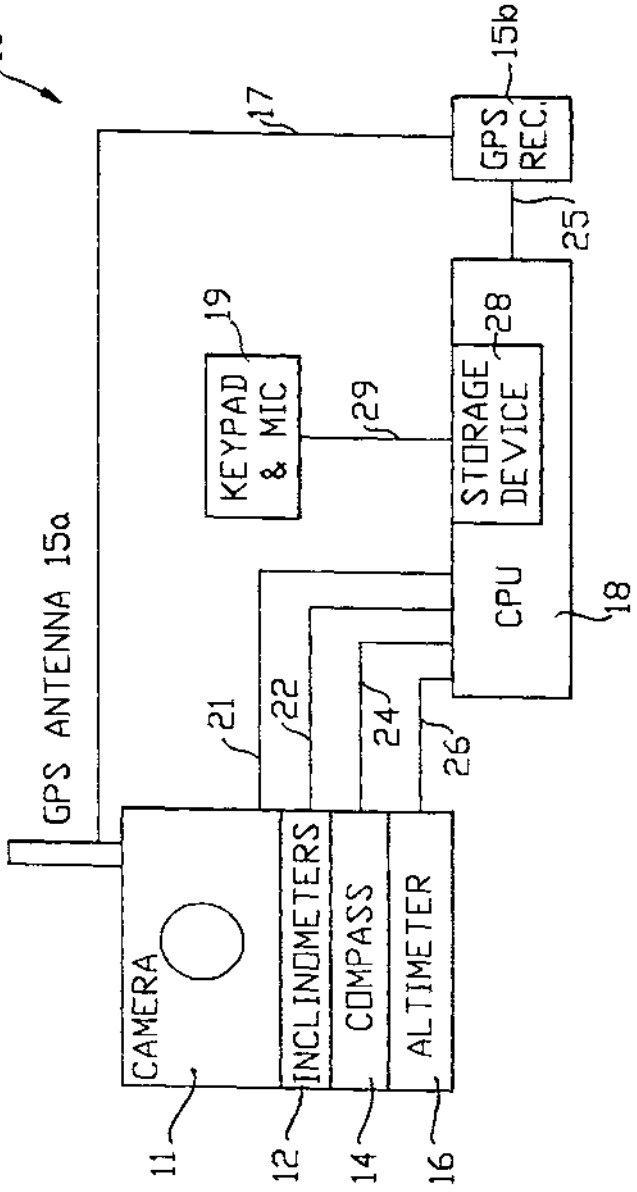


FIG. 1

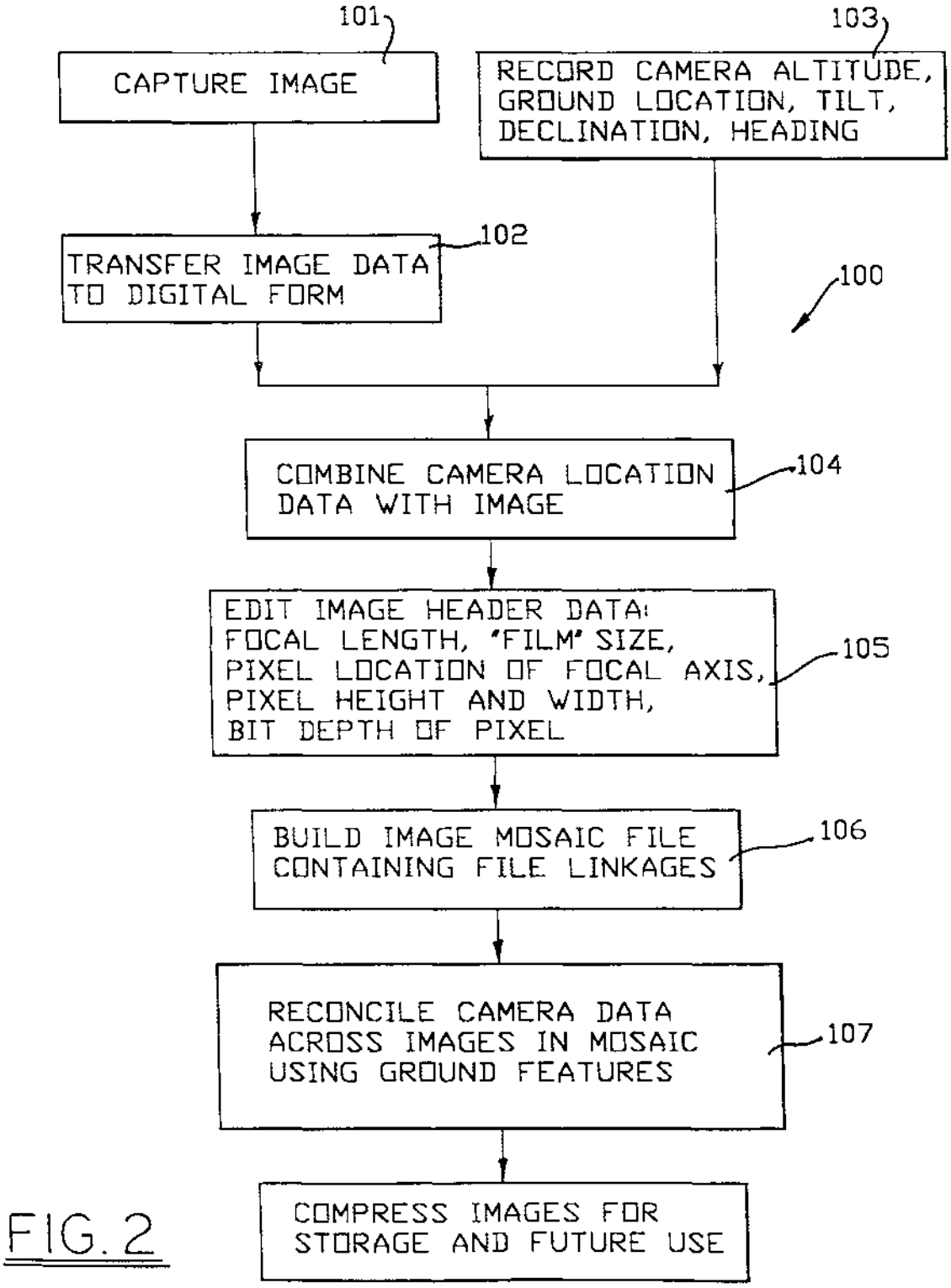

101
CAPTURE IMAGE
103
RECORD CAMERA ALTITUDE, GROUND LOCATION, TILT, DECLINATION, HEADING
102
TRANSFER IMAGE DATA TO DIGITAL FORM
100
COMBINE CAMERA LOCATION DATA WITH IMAGE
104
EDIT IMAGE HEADER DATA: FOCAL LENGTH, "FILM" SIZE, PIXEL LOCATION OF FOCAL AXIS, PIXEL HEIGHT AND WIDTH, BIT DEPTH OF PIXEL
105
BUILD IMAGE MOSAIC FILE CONTAINING FILE LINKAGES
106
RECONCILE CAMERA DATA ACROSS IMAGES IN MOSAIC USING GROUND FEATURES
107
COMPRESS IMAGES FOR STORAGE AND FUTURE USE

FIG. 2

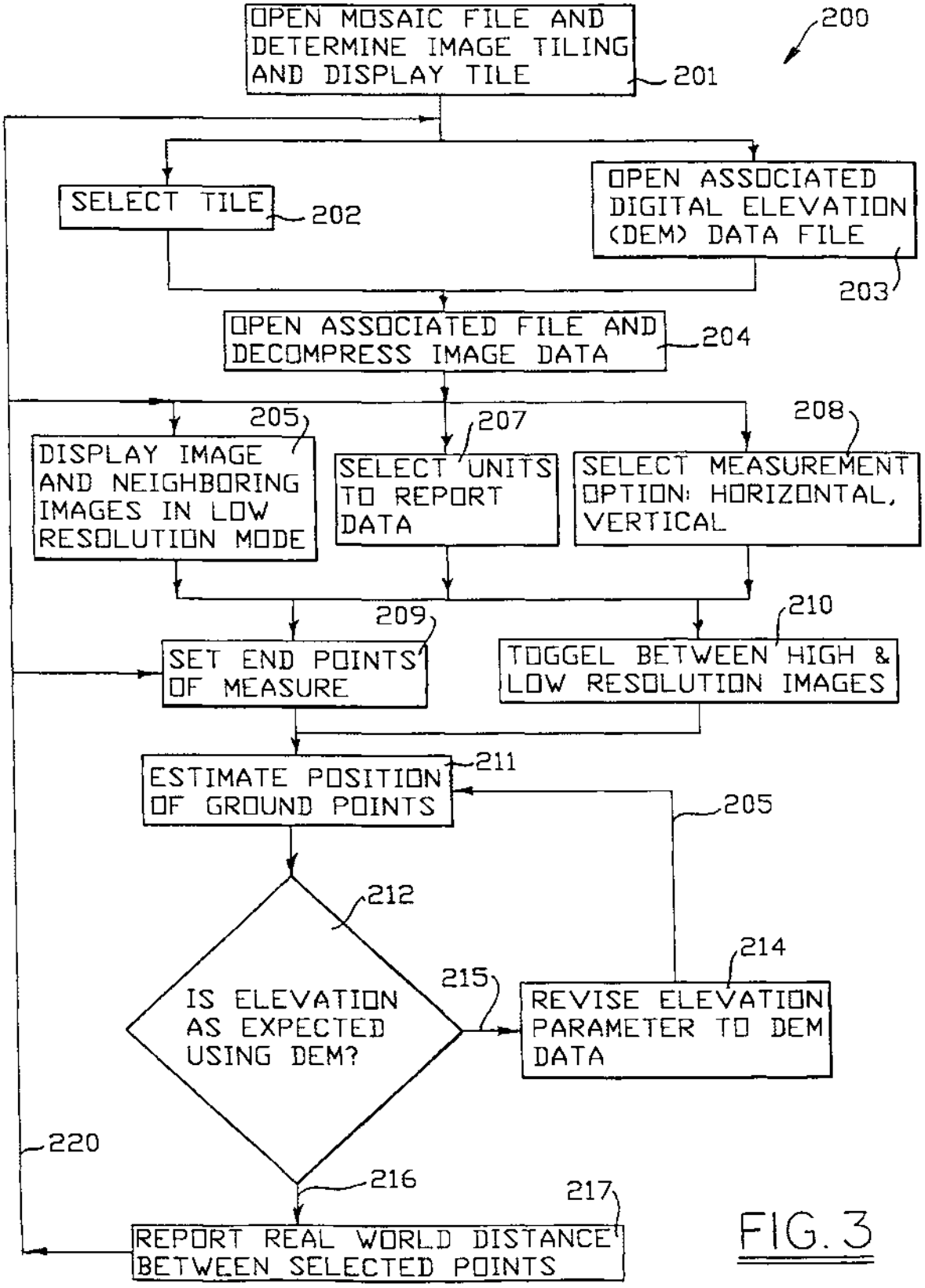

OPEN MOSAIC FILE AND DETERMINE IMAGE TILING AND DISPLAY TILE
200
201
SELECT TILE
202
OPEN ASSOCIATED DIGITAL ELEVATION (DEM) DATA FILE
203
OPEN ASSOCIATED FILE AND DECOMPRESS IMAGE DATA
204
205
DISPLAY IMAGE AND NEIGHBORING IMAGES IN LOW RESOLUTION MODE
207
SELECT UNITS TO REPORT DATA
208
SELECT MEASUREMENT OPTION: HORIZONTAL, VERTICAL
209
SET END POINTS OF MEASURE
210
TOGGEL BETWEEN HIGH & LOW RESOLUTION IMAGES
211
ESTIMATE POSITION OF GROUND POINTS
205
212
IS ELEVATION AS EXPECTED USING DEM?
215
214
REVISE ELEVATION PARAMETER TO DEM DATA
220
216
217
REPORT REAL WORLD DISTANCE BETWEEN SELECTED POINTS

FIG. 3

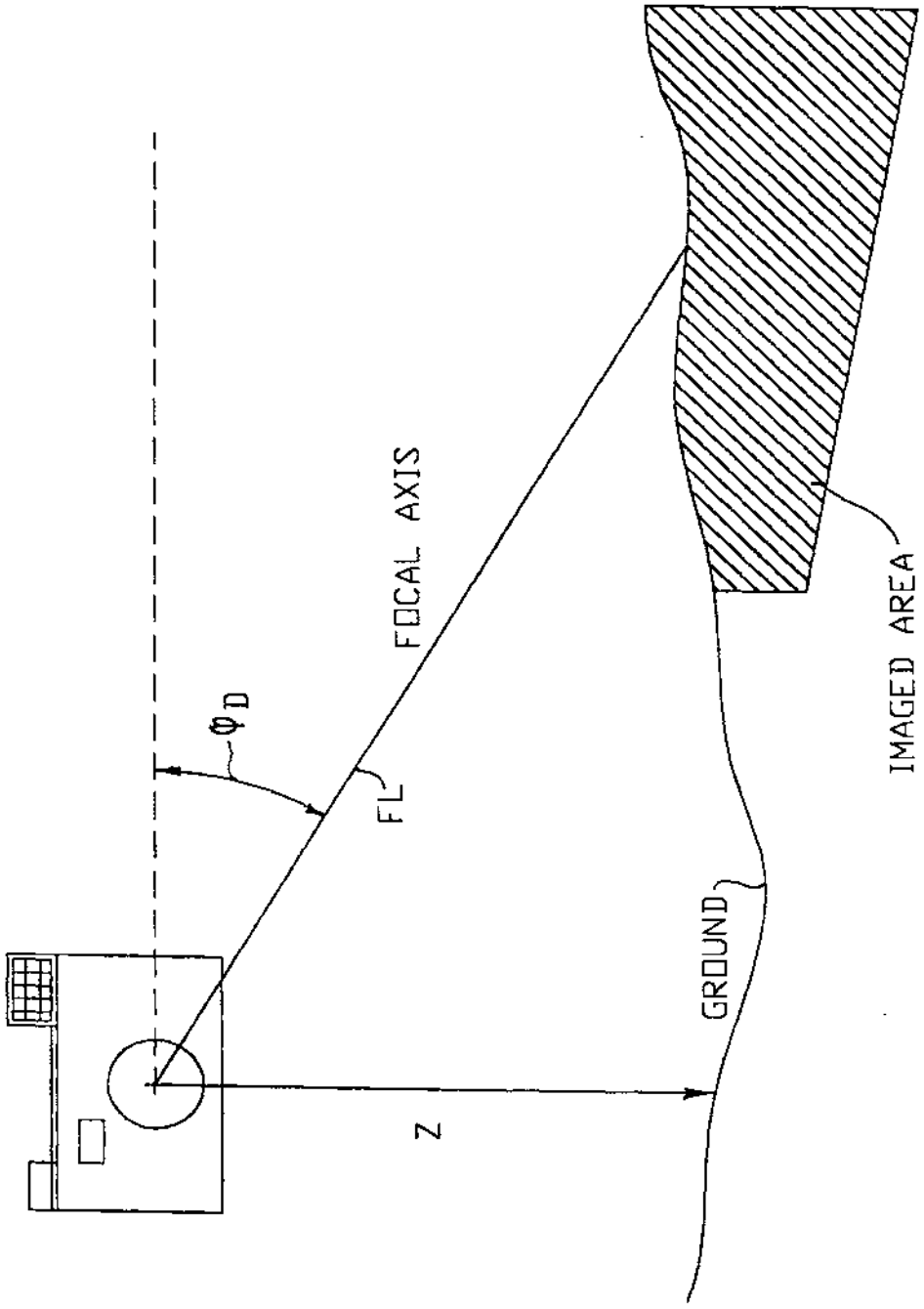


FIG. 4(a)

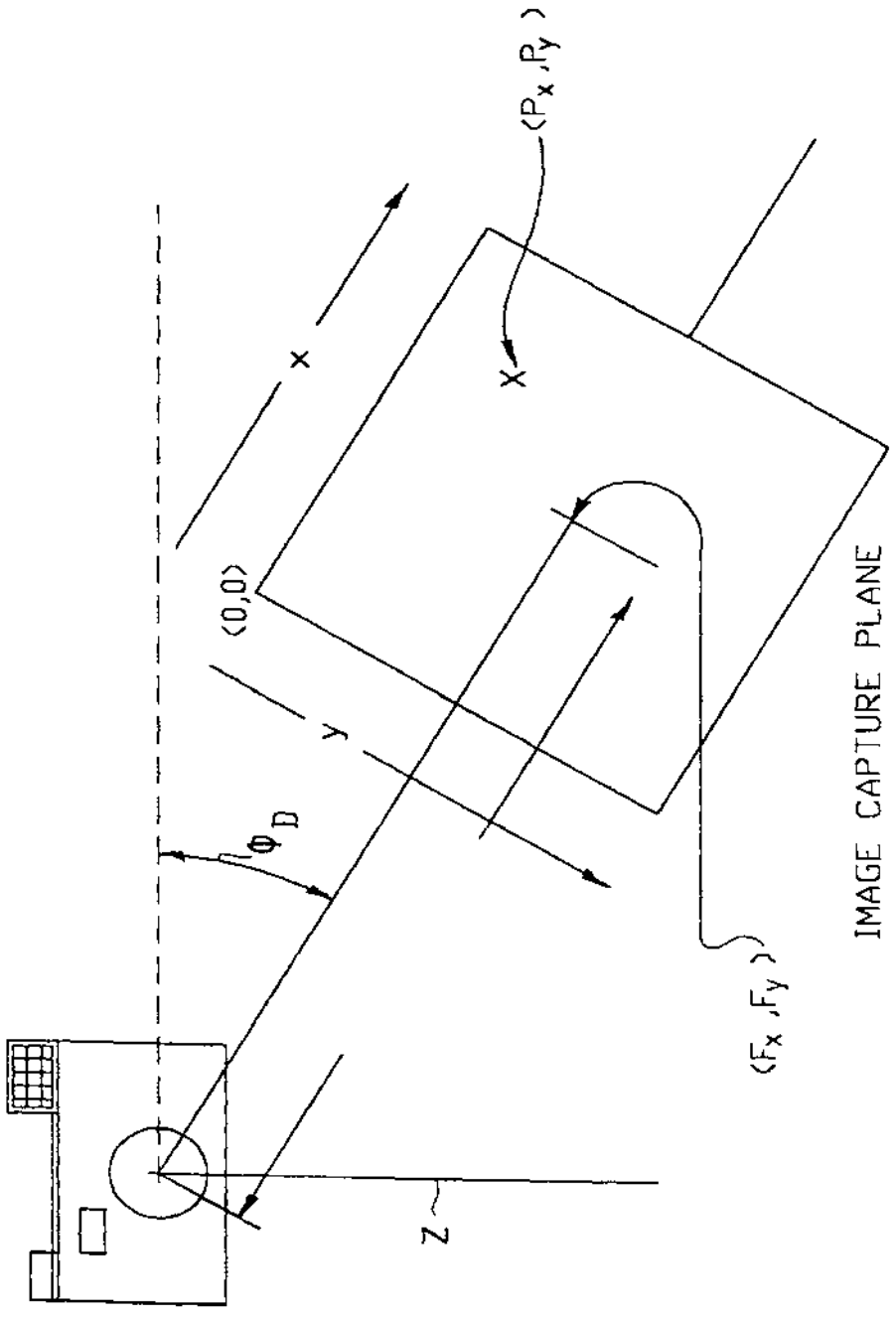


FIG. 4(b)

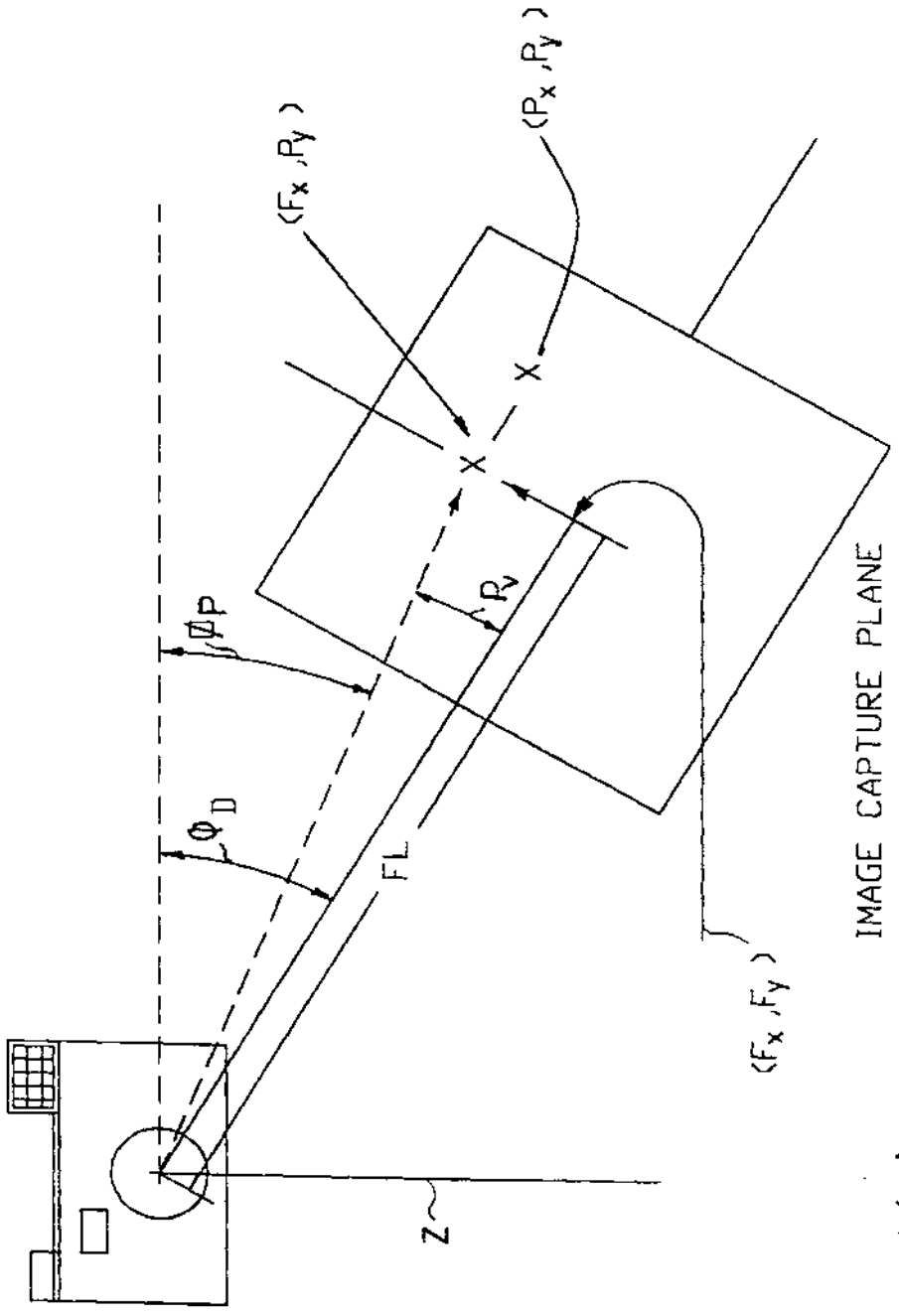


FIG. 4(c)

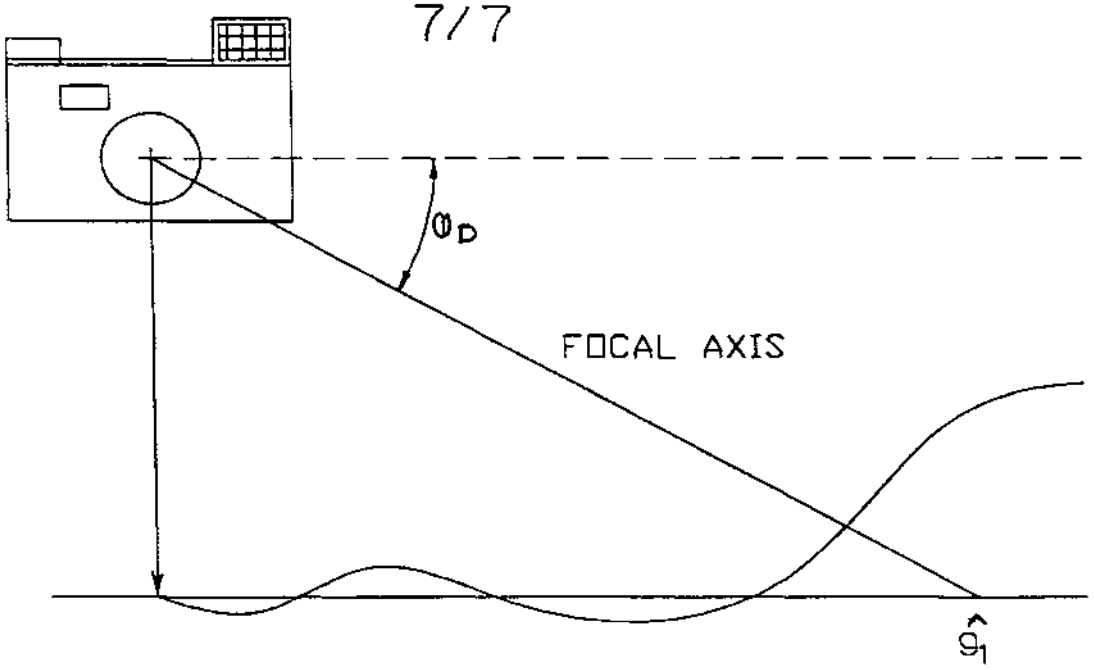

φ_D
FOCAL AXIS
$\hat{g}_1$

FIG. 5(a)

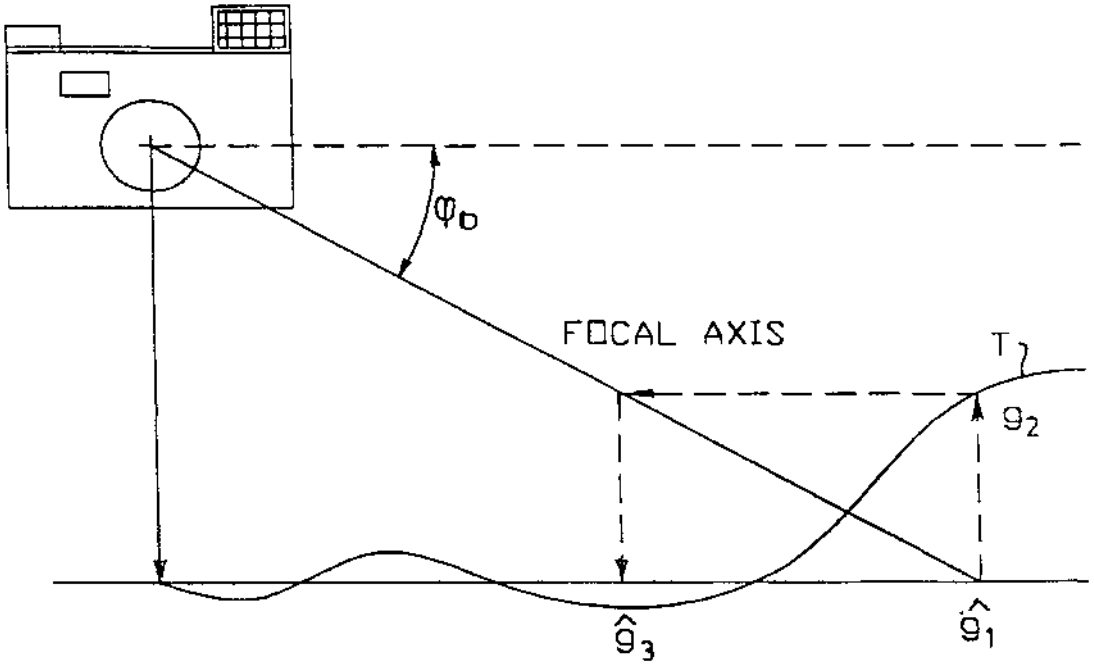

φ_D
FOCAL AXIS
T
g_2
$\hat{g}_3$
$\hat{g}_1$

FIG. 5(b)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/20809

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :Please See Extra Sheet.
US CL :348/143,144,145,148, 373; 354/106; 364/420

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 348/143,144,145,148, 373; 354/106; 364/420

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,467,271 A (ABEL et al.) 14 November 1995, col. 3-30 and Figs. 1-8	10-21, 22-38
Y	US, A, 5,467,271 A (ABEL et al.) 14 November 1995, col. 3-30 and Figs. 1-8	1-9, 22-38
Y	US, A, 5,508,736 A (COOPER) 16 April 1996, col. 3-6 and Fig. 1	1-9, 22-38
A	US, A, 5,506,644 A (SUZUKI et al.) 09 April 1996, Figs. 3 and 9	None

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 NOVEMBER 1998	28 JAN 1999

Name and mailing address of the ISA/US	Authorized officer
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Form PCT/ISA/210 (second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/20809

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (5):

H04N 7/18, 9/47, 5/225; G03B 17/24; G01V 1/00; G01W 1/10; G06F 17/00; G06G 7/48

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : A61B 5/05

A1

(11) International Publication Number: WO 00/53090

(43) International Publication Date: 14 September 2000 (14.09.00)

(21) International Application Number: PCT/US00/06283

(22) International Filing Date: 8 March 2000 (08.03.00)

(30) Priority Data:
09/264,594 8 March 1999 (08.03.99) US

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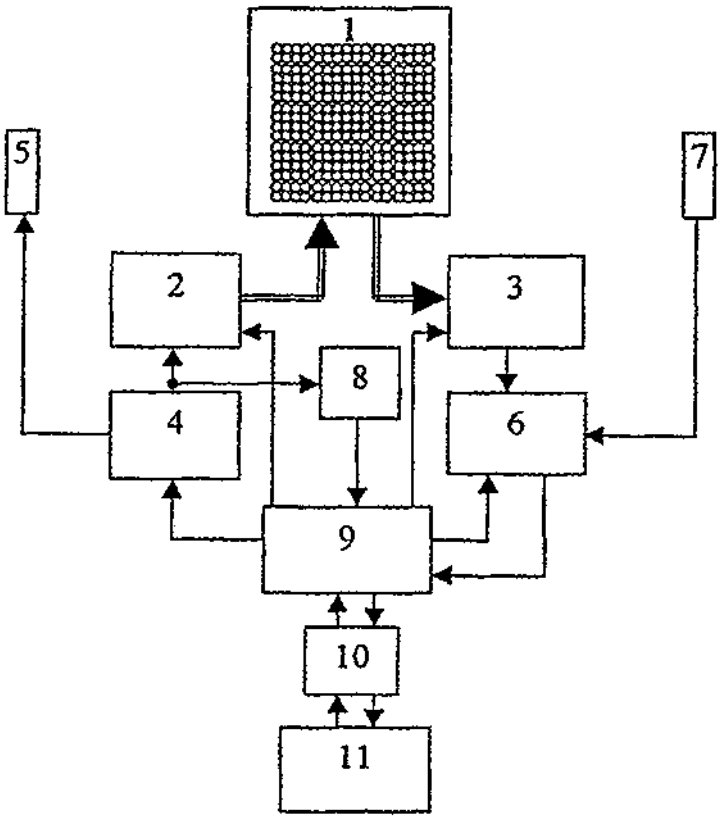
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: ELECTRIC MAMMOGRAPH

(57) Abstract

The electric mammograph is an electrical impedance tomograph device for obtaining three–dimensional images of the conductivity distribution in biological tissues. A planar array of electrodes (1) is put in contact with the tissues of interest. An AC source (4) is connected to a single remotely attached electrode (5, 7) and to one of the planar array electrodes (1). Potential differences between the at rest electrodes in the planar array and a second remote at rest electrode (7, 5) are measured. The images are reconstructed using a modified back projection method.



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ELECTRIC MAMMOGRAPH

Technical Field

The invention is in the field of medical tomography, and in particular relates to a method and apparatus for the visualization and diagnosis of pathologic changes in breast tissues and other organs near the surface of the human body.

Background Art

It is known that electrical conductivity of many tumors, and in particular the malignant tumors of the mammary gland, significantly differs from the conductivity of surrounding sound tissues. This fact may be used for the detection and localization of such tumors.

Some devices are known for visualizing the spatial distribution of conductivity (impedance) in the human body, e.g., electrical impedance tomographs. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," International application PCT/RU97/00398.) In an electrical impedance tomograph, the source of alternating electric current is connected to pairs of electrodes placed along a line on the surface of a body and measurements of the potential differences are made on the other pairs of electrodes. The results of measurements obtained from various combinations of electrodes are used to reconstruct the conductivity distribution with the help of a computer. A three-dimensional distribution of conductivity, however, is not possible with this type of tomograph. Furthermore, its resolution falls significantly from the periphery to the center of contour of the electrodes. Consequently, it is not an adequate device for the diagnosis of mammary gland tumors.

An electroimpedance mammograph device, purporting

to yield a three-dimensional impedance distribution has also been described. (A. Nowakovsky, J. Wortek, and J. Stelter, "A Technical University of Gdansk Electroimpedance Mammograph," Proc. IX Int. Conf. Electrical Bio-Impedance, Heidelberg, 1995, p. 434-437; J. Wortek, J. Stelter, A. Nowakovsky, "Impedance mammograph 3D phantom studies," Proc. X Int. Conf. Electrical Bio-Impedance, Barcelona, 1998, p. 521-524.) This device contains a compact set of electrodes that are placed on the inner surface of a rigid hemisphere, multiplexers that are connected to the source of alternating electric current, and a device for measuring the potential difference between various pairs of electrodes. The measured potential differences are sent to a computer to reconstruct and display the three-dimensional impedance distribution inside the hemisphere. The serviceability of this device based on actual measurements on the human body have not yet been published.

A number of limitations for this device are apparent. The arrangement of electrodes on the hemisphere surface limits the application of the device because the contact with all the electrodes can be provided only for a breast of a definite size. The device also has no means to measure the quality of each contact, nor any means to correct the reconstruction calculations if any of the electrodes have insufficient contact with the body. This decreases the validity of the data. The electric current source and the measuring device are connected to pairs of electrodes placed on the hemisphere, requiring four multiplexers. When the number of electrodes is large, these multiplexers become the most complicated and expensive parts of the device. These multiplexers are also the largest source of spurious signals due to channel-to-channel crosstalk. Only 64 electrodes were used in the prototype. This is obviously insufficient for obtaining satisfactory resolution.

However, further increasing this number is problematical because of the difficulty of commutation by the chosen measuring circuit.

When a safe level of electrical current is used, the measured potential differences are small because of the small distances between electrodes. This decreases the signal-to-noise ratio and the display quality. This effect only gets worse with an increasing number of electrodes. The algorithm for image reconstruction is based on the perturbation method. It requires a calculation time of ten minutes on a workstation for a system of 64 electrodes (Nowakovsky). For 180 electrodes, the minimum necessary for practical applications, about ten hours are required for the calculations based on the estimations of the authors. This amount of time is not feasible for clinical practice.

Other attempts at obtaining three-dimensional electrical impedance images of a body have involved multi-dimensional electrode arrays that surround or partially surround the object being imaged. The reconstruction algorithms used and the methodology of making measurements were also different than those of the present invention. These efforts include U. S. Patents 5,284,142, 5,351,697, 4,263,920, 4,486,835, and 4,539,640.

A goal of the present invention is to provide a new method and apparatus for electric mammography with greater reliability and accuracy of measurements, higher resolution, and increased computational speed. This invention is particularly applicable to the clinical diagnosis of breast tumors and other subsurface areas.

Disclosure of the Invention

The electric mammograph is a device for the measurement and three-dimensional (3-D) reconstruction of the conductivity distribution in biological tissues for clinical diagnoses.

It consists of a compact array of electrodes positioned over the tissue being measured, two additional electrodes spaced apart from the array of electrodes, a source of alternating (AC) current, a means to measure potential difference, and computing means to reconstruct and visualize the resulting conductivity distribution.

Brief Description of the Drawings

The invention is illustrated in the following drawings.

FIG. 1 is a block diagram of the electric mammograph.

FIG. 2 shows the arrangement of the apparatus when conducting a mammograph examination.

FIG. 3 is a block diagram of the algorithm used for the three-dimensional conductivity distribution reconstruction.

FIG. 4 is a photograph of the apparatus

FIG. 5 is a sample electric mammogram.

Description of Preferred Embodiments

A block diagram of the components of the electric mammograph is shown in FIG. 1. A compact array of cylindrical protruding electrodes **1** is arranged in a rigid dielectric plane. The example shown has 256 electrodes. The output multiplexer **2** is connected to the electrode array **1** and is the means by which the alternating current (AC) source **4** is connected to one of the cylindrical electrodes in the array. The input multiplexer **3** serves to connect one of the non-activated or "rest" electrodes of the array to the potential difference measuring unit **6**. The microprocessor **9** and the computer **11**, connected via cables **10**, determine which electrode is activated and which of the rest electrodes is being measured at any given time.

Two single remote electrodes, **5** and **7**, are attached to the extremities of the patient. One remote electrode **5** is connected directly to the AC source. The other remote electrode **7**

is connected directly to the potential difference detector **6**. The AC source is connected to a voltage threshold detector **8**. The operation of the electric mammograph is controlled by a microprocessor/computer means. It gets inputs from the potential difference detector **6** and the threshold detector **8** and outputs to the two multiplexers **2**, **3**, the potential difference detector, and the AC source. The first remote electrode **5** connected to the AC source and the second remote electrode **7** are located on a patient's extremities, e.g., one on each wrist as shown in FIG. 2.

In the prior art methods of obtaining a tomographic image of a human body, a series of contact electrodes were placed on the surface of the patent's body. A source of electric current was connected sequentially to pairs of electrodes causing current to flow through the body. Measurements were then made of potential differences between pairs of other "non-activated" electrodes.

In the present invention, the output multiplexer **2** switches a single lead from the AC source to "activate" a single electrode in the electrode array **1** at a time, instead of activating pairs of electrodes in prior art devices. The second "activated" electrode is the remote electrode **5** that is always "on". Switching a single lead at a time reduces the spurious couplings arising from channel-to-channel penetration of signals in the multiplexer. It also simplifies the device and reduces its cost. The same is true for the input multiplexer **3**. The potential difference detector measures the difference between the selected array electrode and the remote rest electrode **7**. For a given rest electrode, the output multiplexer **2** sequences through all the other electrodes in the compact set while the potential difference detector makes its measurements. Then the rest electrode is switched and the output multiplexer sequence repeated.

Using the two singular electrodes **5**, **7** also increase the amplitude of the measured signals due to the increased distance between the points where the potentials are measured. This increases the signal-to-noise ratio and the accuracy of the measurements. The distance of these singular electrodes from the electrode array allows one to assume that the unperturbed equipotential surfaces of electric field are spherical in the examination area. It simplifies and speeds up the conductivity reconstruction calculations.

The method of back projection along equipotential surfaces of the electric field is used to reconstruct the 3-D conductivity distribution. It is assumed that in the case where the electric current is injected through one of the electrodes of the compact set of electrodes arranged in a planar array and the remote common electrode, equipotential surfaces near the two-dimensional set of electrodes are spherical. The procedure of back projection is reduced to the following. For some point with coordinates (X, Y, Z) inside the object under visualization, the distance is determined between this point and the injecting electrode of the compact array. This distance is equal to the radius r of the equipotential surface containing the point where the conductivity is reconstructed. Knowing this radius, it is possible to determine the line of intersection of the equipotential surface with the surface on which the electrodes are arranged. When the electrodes are arranged on the plane, given by equation $z=0$, this line is the circle lying in the (x, y) plane having its center at the point where the injecting electrode is located, and having radius r. Conductivity S (in arbitrary units) at the chosen point is calculated according to the equation:

$$S(x,y,z) = 1 + W_1(z)\sum_i \frac{1}{\int_{L(x,y,z,i)} W_2(l)dl} \int_{L(x,y,z,i)} W_2(l)(E_r(l) - E_m(l))/E_r(l)dl$$

where i – is the number of the injecting electrode, $L(x,y,z,i)$ - is the line of intersection of the equipotential surface with the surface on which the electrodes are arranged (circle with radius r). The components of the electric field vector $\vec{E}_m$ are first calculated at the nodes of the grid between the electrodes as the potential differences between adjacent electrodes in the x and y directions. Then these components are linearly interpolated to the current point of integration on the line L and the magnitude of this vector E_m is calculated.

The reference intensity of the electric field E_r corresponds to a homogeneous medium and is calculated numerically. Weighting coefficient $W_1(z)$ corrects the decrease of sensitivity with depth. In the present invention, the empirical equation $W_1 = (z+\alpha)/(z+\beta), \alpha << \beta$ is used for it. The weighting coefficient W_2 provides a relatively greater contribution to the calculated conductivity of those points on line L, which are located closer to the point at which the conductivity is reconstructed. In the present device, the equation: $W_2 = 1/R^4 = 1/\left((x-x_l)^2 + (y-y_l)^2 + z^2\right)^2$ is used, where R is the

distance between the point where the conductivity is reconstructed and the current point on the line along which integration is being carried out; the index *l* refers to the coordinates of this point.

The method of back projection is the fastest method used in electrical impedance tomography reconstruction. Its use, however, for reconstructing the static conductivity distribution for the 3-D case is only possible by a proper choice of the projected values.

In addition, the synthesized reference data set E_r must be used. This is obtained by approximating the real measured potentials according to the method of Korjenevsky. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," Russian Federation patent application N 96123647/14.)

In many cases it is difficult to obtain sufficient contact of all the electrodes with the patient's body. Consequently, the threshold detector **8** of the output voltage is used to determine whether the electrode being measured at any particular moment has sufficient contact with the body. The compact set of electrodes is arranged on a rigid dielectric plane and every electrode is a conducting protrusion from the plane. This arrangement permits an examination of a mammary gland regardless of its size. During an examination, this plane of electrodes is pressed against the breast, flattening it toward the chest. This increases the number of electrodes having contact with the body and decreases the thickness of the tissue layer to be measured. The protrusion of the electrodes improves their electrical contact with the body.

One or more of the electrodes on the periphery of the plane may not have contact with the body, depending on the size of the examined object. These electrodes are detected with the help

of the threshold detector of the output voltage mentioned above. The values of the potential differences measured from electrodes that have insufficient body contact cannot be used directly in the process of conductivity reconstruction. Instead, values of potential differences calculated on the assumption of a homogeneous conductivity distribution are used.

Besides the useful potential differences caused by the current flow, there are also galvanic potential differences between electrodes. The component for measuring the potential difference **6** is only sensitive to the alternating current component and, consequently, is not disturbed by the presence of these constant galvanic potential differences. However, due to the differences in galvanic potentials of different electrodes, the input voltage varies by a jump when the input multiplexer **3** is switched. These jumps produce a transient that influences the results of the measurements. This influence increases when the time interval between the switch and the start of the potential difference measurement decreases. Therefore, to decrease the error while keeping the total duration of the measurements constant, the input multiplexer **3** should switch the device for measuring the potential difference **6** to the next electrode only after the output multiplexer **2** completes the total cycle of switches of the AC source to all other electrodes.

FIG. 2 shows the arrangement of the various components of the electric mammograph used to take measurements. With the help of the output multiplexer, the control unit connects the source of AC current to one of the electrodes of compact set **1** according to commands from the computer **11**. AC current of approximately 1 mA and a frequency of 10 kHz flows through the circuit, i.e., from the AC source to the multiplexer, to the electrode of set **1**, through the patient's body to the remote rest

electrode **5**. With the help of the input multiplexer, the microprocessor connects one of the rest electrodes from set **1** to the potential difference detector. It measures the amplitude of the alternating voltage between the electrode from set **1** and the remote activated electrode **7**. This measurement is sent in digital code to the microprocessor, which passes it to the computer **11**.

The measured data are used to reconstruct a 3-D conductivity distribution with the help of the algorithm shown in block diagram form in FIG. 3. In block **12** the measured potentials of the electrodes from the compact set, received through the connection line **10**, are used for synthesis of the reference set of potentials corresponding to a body with homogeneous conductivity. An approximation by the method of least squares described in Russian Patent N 96123647/14 is used. Only those potentials obtained from electrodes with good body contact are used. In blocks **13** and **14**, components of the electric intensity vector are calculated for the reference and measured data set by subtraction of the values of potentials on adjacent electrodes for each variant of connection of the current source. In the last case, corresponding potentials from the reference set are used instead of the potentials of those electrodes with insufficient contact.

In block **15** the distance is calculated between the activated electrode in the compact set and the point at which the conductivity is being reconstructed. This distance determines the radius of a circle that represents the line of intersection of the equipotential surface with the plane on which the electrodes are arranged and along which it is necessary to carry out weighted averaging. The electric intensity for the measured and the reference data set are calculated after the linear interpolation of the corresponding components of vectors, calculated in blocks **13** and

14. The relative difference of the electric intensities for the reference and measured data sets are multiplied by the weight function $1/R^4$, where R is the distance between the point where the conductivity is reconstructed and the current point on the line along which averaging is being carried out.

In block **16** the obtained value is numerically integrated along the circle. These operations are repeated for all points where the conductivity is to be reconstructed and for all variants of the activated electrodes. This process is controlled by block **17**. The result of these calculations, after adding a unit to obtained values, represents a 3-D distribution of the conductivity normalized on the average value. The result can be displayed on screen or printed out. Block **18** contains the software and hardware used to carry out these functions.

The external appearance of the electric mammograph without the computing unit is shown in FIG. 4. FIG. 5 shows an electric mammogram obtained by the invention. The mammogram represents a set of seven images of breast cross-sections parallel to the plane on which the electrodes are arranged. The depth of the cross-sections increases from left to right and from up to down with 8 mm steps. On the image one can clearly see the nipple 19, the ribs **20**, and the boundary **21** between areas with and without sufficient electrode contact with the body.

CLAIMS

1. A method of displaying a three-dimensional image of the conductivity distribution of biological tissue, said method comprising the steps of:

applying a source (4) of alternating current (AC) to a first activated electrode (1) of a compact set of electrodes arranged in a planar array, said compact set of electrodes being in contact with the surface of the biological tissues of interest, and to a first remotely located electrode (5, 7) in contact with the body but at some distance from the compact set of electrodes;

measuring the potential difference between a first at rest electrode (1) of said compact set and a second remotely located electrode (7,5), said second remote electrode being at rest;

switching the source (4) of AC current by multiplexer means (2, 3) to activate successively all of the electrodes (1) of said planar array of electrodes except said at rest electrode of step (b) and measuring the potential difference between said at rest electrodes in (b) for each activated electrode in turn to thereby obtain a first set of potential difference measurements for each activated electrode;

switching the electrode (1) to be measured in said planar array by multiplexer means (2, 3) to a second at rest electrode (1), activating successively every other electrode in said planar array, and measuring the potential difference between said second at rest electrode and said at rest remote electrode (7, 5) in turn to thereby obtain a second set of potential difference measurements for each activated electrode;

continue switching the at rest electrode (1), activating successively the remaining electrodes in said planar array, and measuring the potential difference between the selected at rest

electrode and said at rest remote electrode (7, 5) in turn until all planar electrodes combinations have been measured;

reconstructing a three-dimensional conductivity distribution using the method of back projection along equipotential surfaces of the electric field, the projected data being obtained by weighted averaging of the relative difference between the reference electric intensity corresponding to tissue with a homogeneous conductivity distribution and the measured electric intensity along the line of intersection of the equipotential surface containing the point where conductivity is reconstructed and with the surface on which the compact set of electrodes (1) is located.

2. The method of claim 1, whereby a threshold detector means (8) determines whether any particular electrode (1) of the planar array has sufficient contact with the tissue to give a meaningful measurement.

3. The method of claim 2, whereby the values of potential differences for those electrodes (1) having insufficient contact with the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

4. The method of claim 1, whereby the weighting coefficient of $1/R^4$ is used in the weighted averaging of step (f), where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

5. The method of claim 1, whereby said compact set of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

6. An apparatus for producing a three-dimensional image of the conductivity distribution of biological tissue comprising:

a plurality of individual electrodes (1) disposed in a rigid planar array and placed in contact with the biological tissue of interest;

an alternating current (AC) source (4) connected to one of the electrodes (active electrode) (1) in said planar array and to a single remote active electrode (5, 7) located at some distance from said planar array and in contact with the biological tissue;

an output multiplexing means (2) to successively switch the AC source to other electrodes (1) in said planar array making them active electrodes in turn;

an input multiplexing means (3) to connect a potential difference measuring means (6) to one of the non-active (at rest) electrodes (1) in said planar array and to an at rest single remote electrode (7, 5) located at some distance from said planar array and in contact with the biological tissue;

computing means coupled to said input and output multiplexing means (2, 3) for sequencing said AC source through said planar array electrodes (1) while taking potential difference measurements from other electrodes in said planar array and for reconstructing a three-dimensional conductivity distribution using a modified back projection method; and

display means for imaging the reconstructed three-dimensional conductivity distribution.

7. The apparatus of claim 6, wherein a threshold detector means (8) is provided to determine whether any particular electrode (1) of said planar array has sufficient contact with the tissue to give a meaningful measurement.

8. The apparatus of claim 7, wherein in reconstructing the conductivity distribution, the values of potential differences for those electrodes (1) having insufficient contact with

the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

9. The apparatus of claim 6, wherein the modified back projection reconstruction method used incorporates a weighting coefficient of $1/R^4$, where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

10. The apparatus of claim 6, wherein said planar array of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

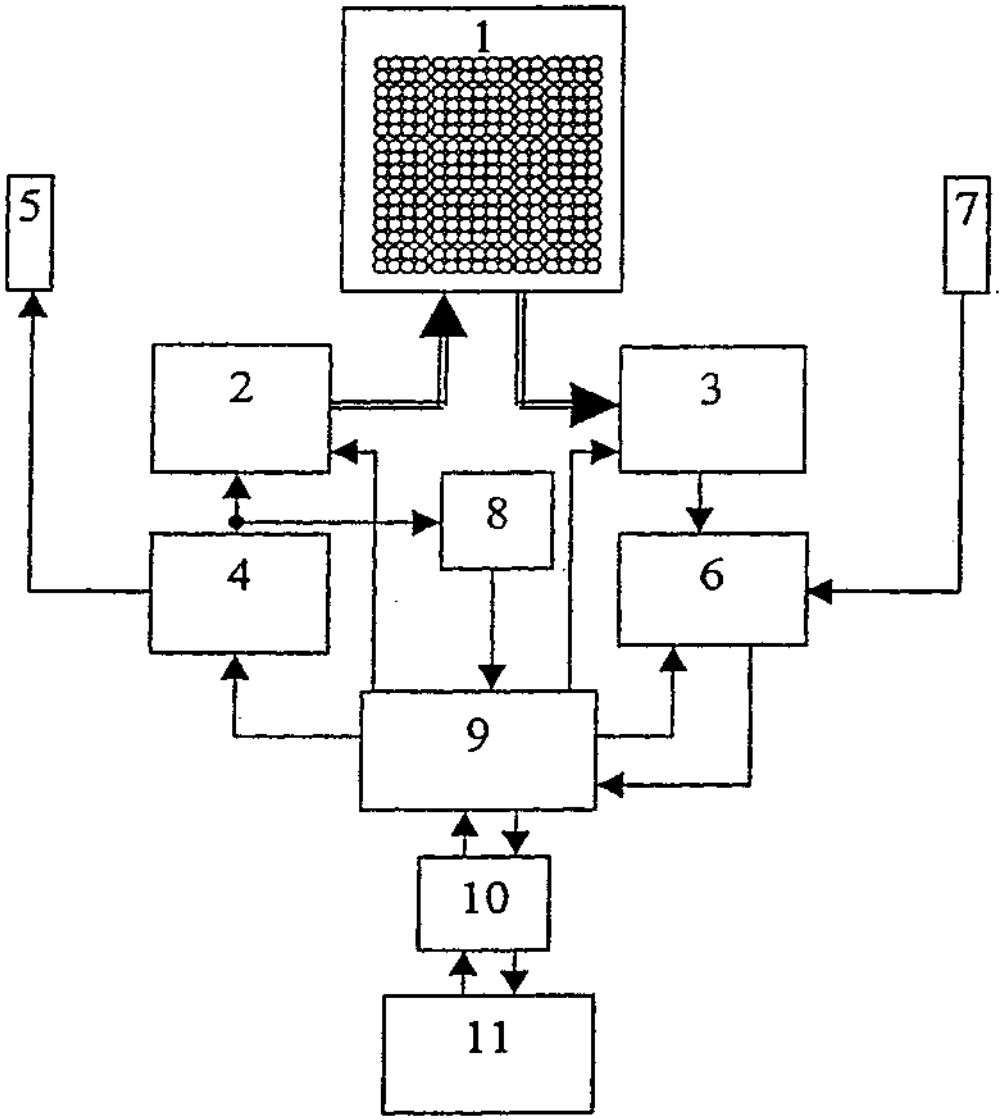


FIG. 1

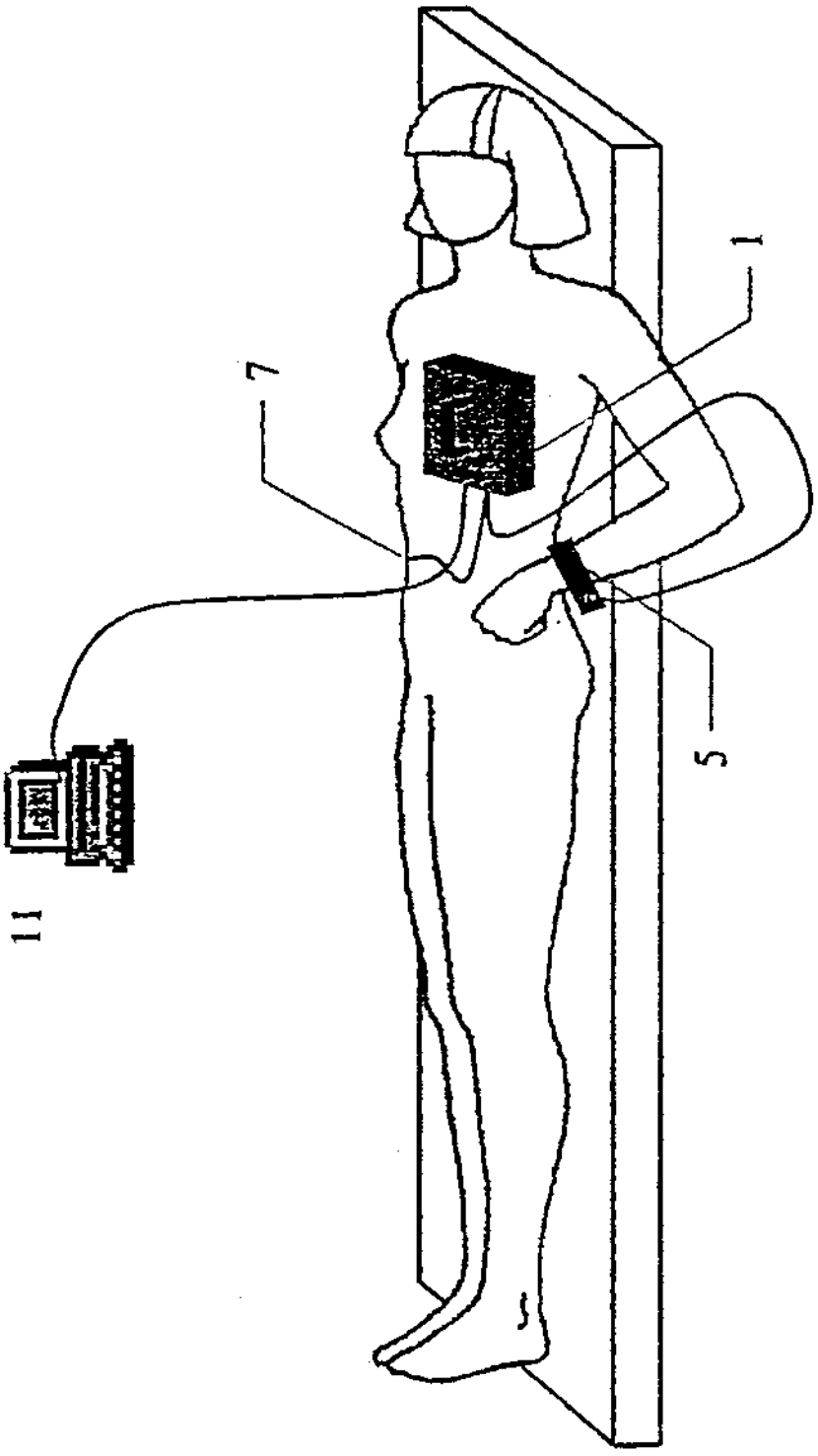


FIG. 2

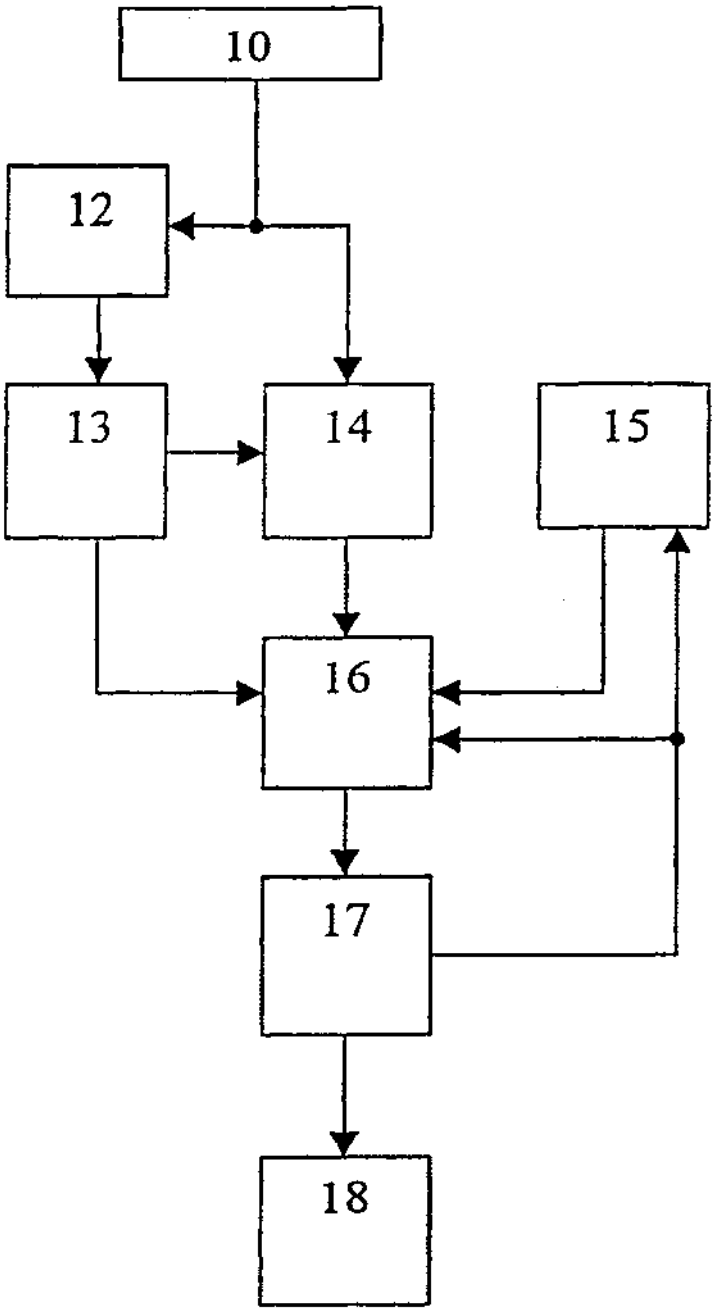


FIG. 3

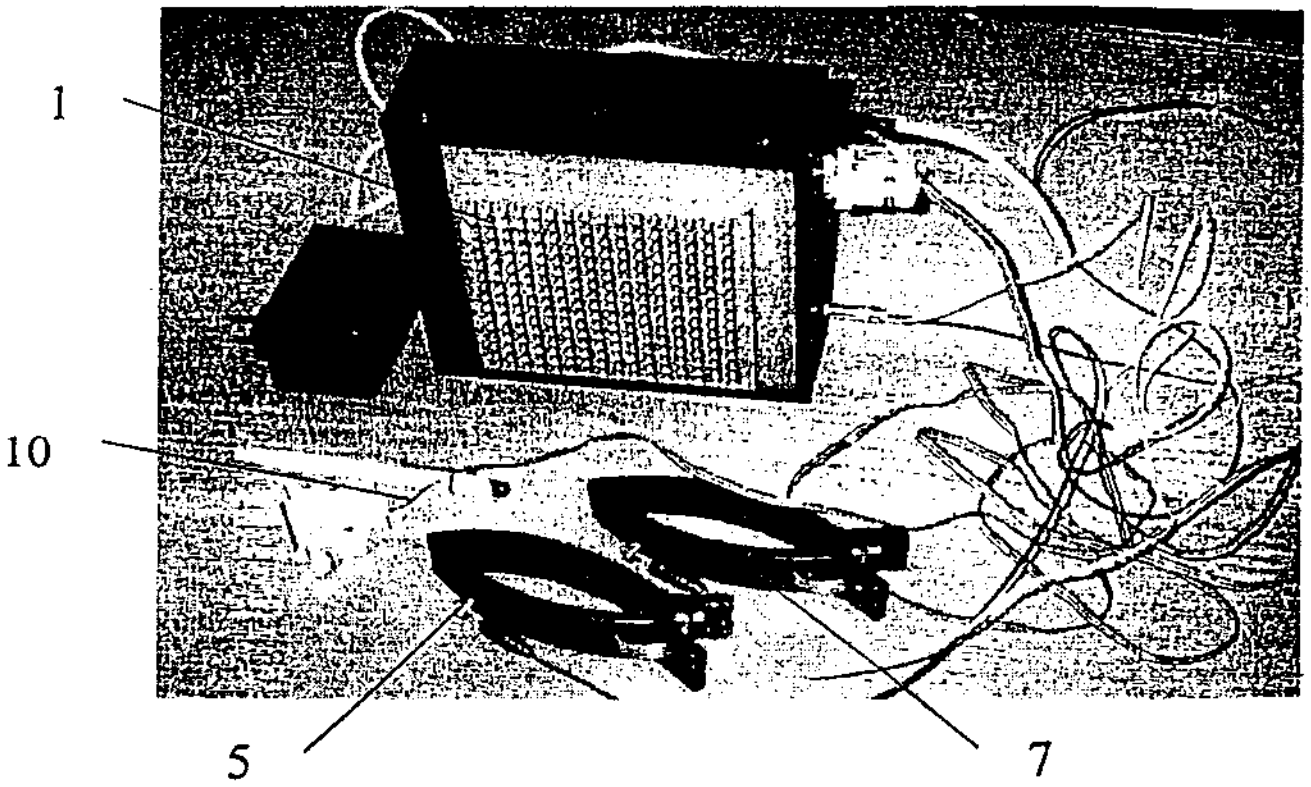


FIG. 4

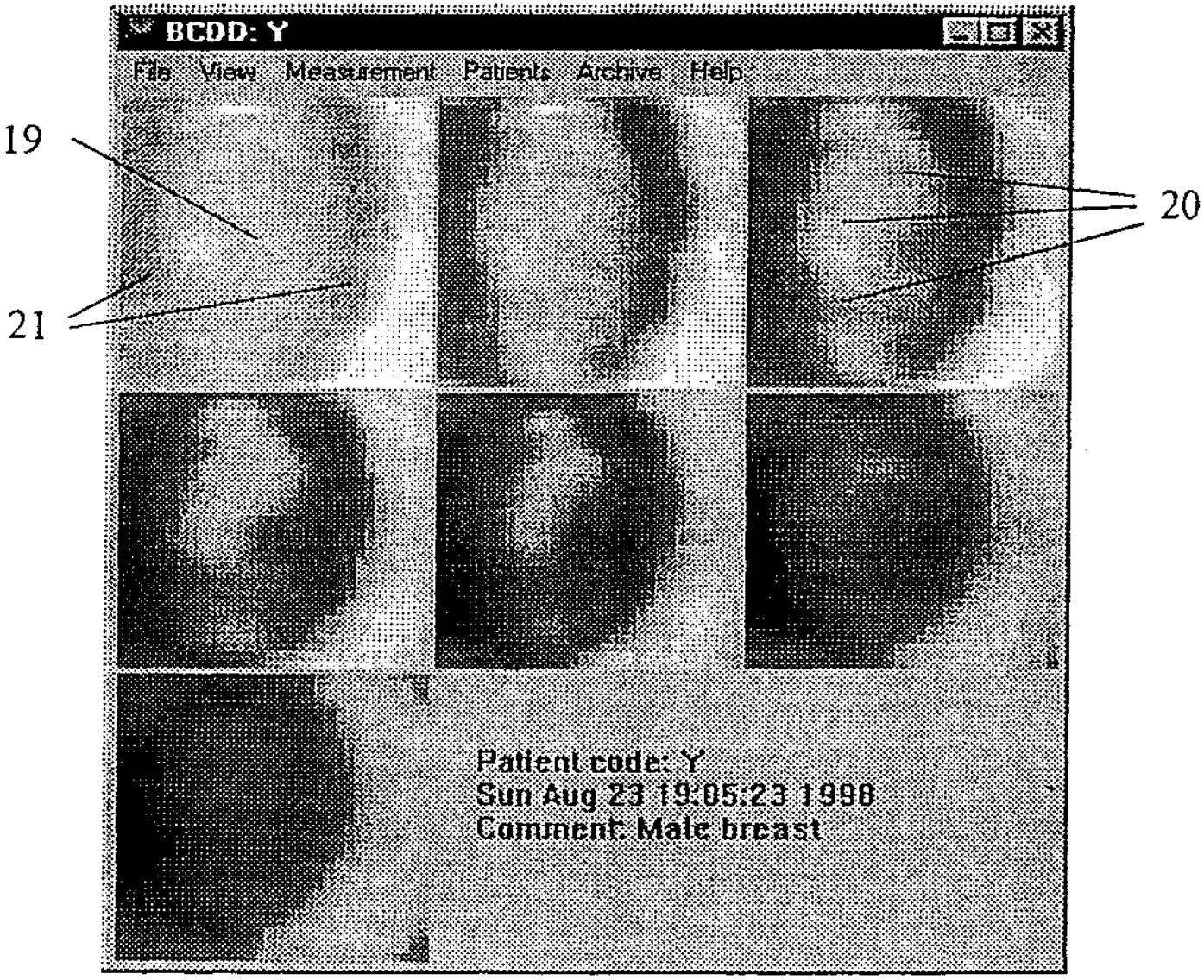

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Comment: Male breast

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06283

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61B 5/05
US CL :128/930; 324/717; 600/547

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/930; 324/600, 713, 717, 600/547

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,351,697 A (CHENEY et al.) 04 October 1994, Abstract	1, 6

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Date of the actual completion of the international search 03 MAY 2000	Date of mailing of the international search report 19 MAY 2000
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CA 2402234 A1 2000/09/14

(21) 2 402 234

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2000/03/08
(87) Date publication PCT/PCT Publication Date: 2000/09/14
(85) Entrée phase nationale/National Entry: 2002/09/06
(86) N° demande PCT/PCT Application No.: US 2000/006263
(87) N° publication PCT/PCT Publication No.: 2000/053090
(30) Priorité/Priority: 1999/03/08 (09/264,594) US

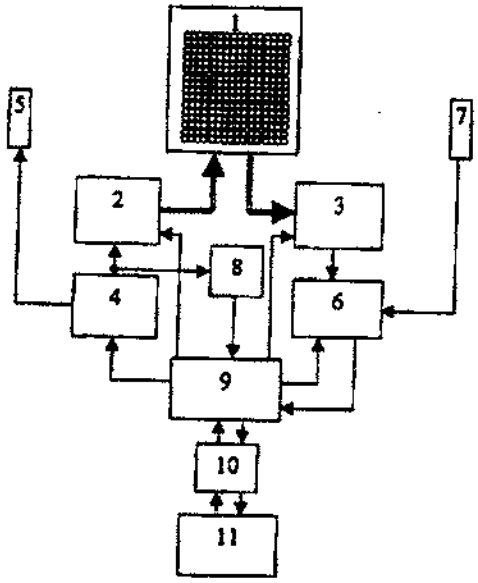
(51) Cl. Int.[7]/Int. Cl.[7] A61B 5/05

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(54) Titre : APPAREIL DE MAMMOGRAPHIE ELECTRIQUE
(54) Title: ELECTRIC MAMMOGRAPH



(57) Abrégé/Abstract
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Roofr Exhibit 1002, Page 191

CA 2402234 A1 2000/09/14

(21) 2 402 234

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2000/03/08
(87) Date publication PCT/PCT Publication Date: 2000/09/14
(85) Entrée phase nationale/National Entry: 2002/09/06
(86) N° demande PCT/PCT Application No.: US 2000/006283
(87) N° publication PCT/PCT Publication No.: 2000/053090
(30) Priorité/Priority: 1999/03/08 (09/264,594) US

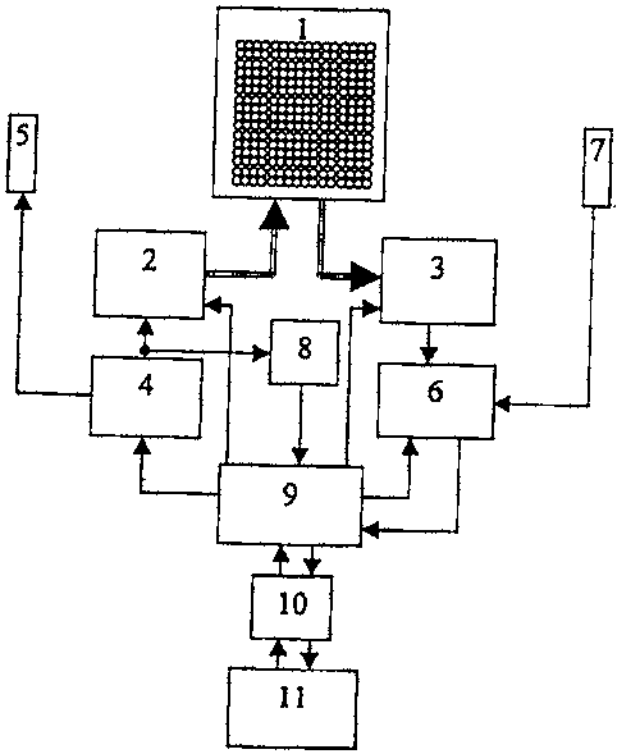
(51) Cl.Int.^{7}/Int.Cl.^{7} A61B 5/05

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :
A61B 5/05

A1

(11) International Publication Number: WO 00/53090

(43) International Publication Date: 14 September 2000 (14.09.00)

(21) International Application Number: PCT/US00/06283

(22) International Filing Date: 8 March 2000 (08.03.00)

(30) Priority Data:
09/264,594 8 March 1999 (08.03.99) US

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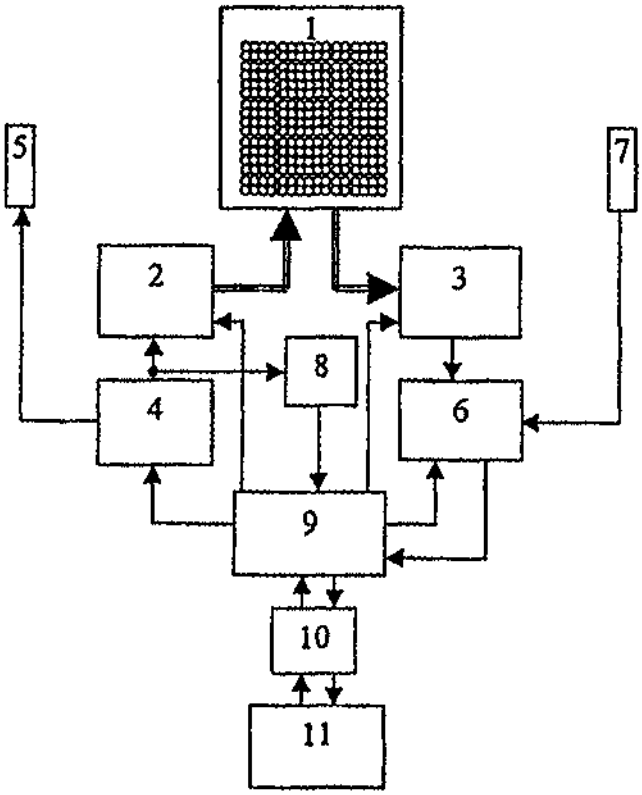
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

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CLAIMS

1. A method of displaying a three-dimensional image of the conductivity distribution of biological tissue, said method comprising the steps of:

applying a source (4) of alternating current (AC) to a first activated electrode (1) of a compact set of electrodes arranged in a planar array, said compact set of electrodes being in contact with the surface of the biological tissues of interest, and to a first remotely located electrode (5, 7) in contact with the body but at some distance from the compact set of electrodes;

measuring the potential difference between a first at rest electrode (1) of said compact set and a second remotely located electrode (7,5), said second remote electrode being at rest;

switching the source (4) of AC current by multiplexer means (2, 3) to activate successively all of the electrodes (1) of said planar array of electrodes except said at rest electrode of step (b) and measuring the potential difference between said at rest electrodes in (b) for each activated electrode in turn to thereby obtain a first set of potential difference measurements for each activated electrode;

switching the electrode (1) to be measured in said planar array by multiplexer means (2, 3) to a second at rest electrode (1), activating successively every other electrode in said planar array, and measuring the potential difference between said second at rest electrode and said at rest remote electrode (7, 5) in turn to thereby obtain a second set of potential difference measurements for each activated electrode;

continue switching the at rest electrode (1), activating successively the remaining electrodes in said planar array, and measuring the potential difference between the selected at rest

electrode and said at rest remote electrode (7, 5) in turn until all planar electrodes combinations have been measured;

reconstructing a three-dimensional conductivity distribution using the method of back projection along equipotential surfaces of the electric field, the projected data being obtained by weighted averaging of the relative difference between the reference electric intensity corresponding to tissue with a homogeneous conductivity distribution and the measured electric intensity along the line of intersection of the equipotential surface containing the point where conductivity is reconstructed and with the surface on which the compact set of electrodes (1) is located.

2. The method of claim 1, whereby a threshold detector means (8) determines whether any particular electrode (1) of the planar array has sufficient contact with the tissue to give a meaningful measurement.

3. The method of claim 2, whereby the values of potential differences for those electrodes (1) having insufficient contact with the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

4. The method of claim 1, whereby the weighting coefficient of $1/R^4$ is used in the weighted averaging of step (f), where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

5. The method of claim 1, whereby said compact set of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

6. An apparatus for producing a three-dimensional image of the conductivity distribution of biological tissue comprising:

a plurality of individual electrodes (1) disposed in a rigid planar array and placed in contact with the biological tissue of interest;

an alternating current (AC) source (4) connected to one of the electrodes (active electrode) (1) in said planar array and to a single remote active electrode (5, 7) located at some distance from said planar array and in contact with the biological tissue;

an output multiplexing means (2) to successively switch the AC source to other electrodes (1) in said planar array making them active electrodes in turn;

an input multiplexing means (3) to connect a potential difference measuring means (6) to one of the non-active (at rest) electrodes (1) in said planar array and to an at rest single remote electrode (7, 5) located at some distance from said planar array and in contact with the biological tissue;

computing means coupled to said input and output multiplexing means (2, 3) for sequencing said AC source through said planar array electrodes (1) while taking potential difference measurements from other electrodes in said planar array and for reconstructing a three-dimensional conductivity distribution using a modified back projection method; and

display means for imaging the reconstructed three-dimensional conductivity distribution.

7. The apparatus of claim 6, wherein a threshold detector means (8) is provided to determine whether any particular electrode (1) of said planar array has sufficient contact with the tissue to give a meaningful measurement.

8. The apparatus of claim 7, wherein in reconstructing the conductivity distribution, the values of potential differences for those electrodes (1) having insufficient contact with

the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

9. The apparatus of claim 6, wherein the modified back projection reconstruction method used incorporates a weighting coefficient of $1/R^4$, where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

10. The apparatus of claim 6, wherein said planar array of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

ELECTRIC MAMMOGRAPH

Technical Field

The invention is in the field of medical tomography, and in particular relates to a method and apparatus for the visualization and diagnosis of pathologic changes in breast tissues and other organs near the surface of the human body.

Background Art

It is known that electrical conductivity of many tumors, and in particular the malignant tumors of the mammary gland, significantly differs from the conductivity of surrounding sound tissues. This fact may be used for the detection and localization of such tumors.

Some devices are known for visualizing the spatial distribution of conductivity (impedance) in the human body, e.g., electrical impedance tomographs. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," International application PCT/RU97/00398.) In an electrical impedance tomograph, the source of alternating electric current is connected to pairs of electrodes placed along a line on the surface of a body and measurements of the potential differences are made on the other pairs of electrodes. The results of measurements obtained from various combinations of electrodes are used to reconstruct the conductivity distribution with the help of a computer. A three-dimensional distribution of conductivity, however, is not possible with this type of tomograph. Furthermore, its resolution falls significantly from the periphery to the center of contour of the electrodes. Consequently, it is not an adequate device for the diagnosis of mammary gland tumors.

An electroimpedance mammograph device, purporting

to yield a three-dimensional impedance distribution has also been described. (A. Nowakovsky, J. Wortek, and J. Stelter, "A Technical University of Gdansk Electroimpedance Mammograph," Proc. IX Int. Conf. Electrical Bio-Impedance, Heidelberg, 1995, p. 434-437; J. Wortek, J. Stelter, A. Nowakovsky, "Impedance mammograph 3D phantom studies," Proc. X Int. Conf. Electrical Bio-Impedance, Barcelona, 1998, p. 521-524.) This device contains a compact set of electrodes that are placed on the inner surface of a rigid hemisphere, multiplexers that are connected to the source of alternating electric current, and a device for measuring the potential difference between various pairs of electrodes. The measured potential differences are sent to a computer to reconstruct and display the three-dimensional impedance distribution inside the hemisphere. The serviceability of this device based on actual measurements on the human body have not yet been published.

A number of limitations for this device are apparent. The arrangement of electrodes on the hemisphere surface limits the application of the device because the contact with all the electrodes can be provided only for a breast of a definite size. The device also has no means to measure the quality of each contact, nor any means to correct the reconstruction calculations if any of the electrodes have insufficient contact with the body. This decreases the validity of the data. The electric current source and the measuring device are connected to pairs of electrodes placed on the hemisphere, requiring four multiplexers. When the number of electrodes is large, these multiplexers become the most complicated and expensive parts of the device. These multiplexers are also the largest source of spurious signals due to channel-to-channel crosstalk. Only 64 electrodes were used in the prototype. This is obviously insufficient for obtaining satisfactory resolution.

However, further increasing this number is problematical because of the difficulty of commutation by the chosen measuring circuit.

When a safe level of electrical current is used, the measured potential differences are small because of the small distances between electrodes. This decreases the signal-to-noise ratio and the display quality. This effect only gets worse with an increasing number of electrodes. The algorithm for image reconstruction is based on the perturbation method. It requires a calculation time of ten minutes on a workstation for a system of 64 electrodes (Nowakovsky). For 180 electrodes, the minimum necessary for practical applications, about ten hours are required for the calculations based on the estimations of the authors. This amount of time is not feasible for clinical practice.

Other attempts at obtaining three-dimensional electrical impedance images of a body have involved multi-dimensional electrode arrays that surround or partially surround the object being imaged. The reconstruction algorithms used and the methodology of making measurements were also different than those of the present invention. These efforts include U. S. Patents 5,284,142, 5,351,697, 4,263,920, 4,486,835, and 4,539,640.

A goal of the present invention is to provide a new method and apparatus for electric mammography with greater reliability and accuracy of measurements, higher resolution, and increased computational speed. This invention is particularly applicable to the clinical diagnosis of breast tumors and other subsurface areas.

Disclosure of the Invention

The electric mammograph is a device for the measurement and three-dimensional (3-D) reconstruction of the conductivity distribution in biological tissues for clinical diagnoses.

It consists of a compact array of electrodes positioned over the tissue being measured, two additional electrodes spaced apart from the array of electrodes, a source of alternating (AC) current, a means to measure potential difference, and computing means to reconstruct and visualize the resulting conductivity distribution.

Brief Description of the Drawings

The invention is illustrated in the following drawings.

FIG. 1 is a block diagram of the electric mammograph.

FIG. 2 shows the arrangement of the apparatus when conducting a mammograph examination.

FIG. 3 is a block diagram of the algorithm used for the three-dimensional conductivity distribution reconstruction.

FIG. 4 is a photograph of the apparatus

FIG. 5 is a sample electric mammogram.

Description of Preferred Embodiments

A block diagram of the components of the electric mammograph is shown in FIG. 1. A compact array of cylindrical protruding electrodes **1** is arranged in a rigid dielectric plane. The example shown has 256 electrodes. The output multiplexer **2** is connected to the electrode array **1** and is the means by which the alternating current (AC) source **4** is connected to one of the cylindrical electrodes in the array. The input multiplexer **3** serves to connect one of the non-activated or "rest" electrodes of the array to the potential difference measuring unit **6**. The microprocessor **9** and the computer **11,** connected via cables **10,** determine which electrode is activated and which of the rest electrodes is being measured at any given time.

Two single remote electrodes, **5** and **7**, are attached to the extremities of the patient. One remote electrode **5** is connected directly to the AC source. The other remote electrode **7**

is connected directly to the potential difference detector **6**. The AC source is connected to a voltage threshold detector **8**. The operation of the electric mammograph is controlled by a microprocessor/computer means. It gets inputs from the potential difference detector **6** and the threshold detector **8** and outputs to the two multiplexers **2**, **3**, the potential difference detector, and the AC source. The first remote electrode **5** connected to the AC source and the second remote electrode **7** are located on a patient's extremities, e.g., one on each wrist as shown in FIG. 2.

In the prior art methods of obtaining a tomographic image of a human body, a series of contact electrodes were placed on the surface of the patent's body. A source of electric current was connected sequentially to pairs of electrodes causing current to flow through the body. Measurements were then made of potential differences between pairs of other "non-activated" electrodes.

In the present invention, the output multiplexer **2** switches a single lead from the AC source to "activate" a single electrode in the electrode array **1** at a time, instead of activating pairs of electrodes in prior art devices. The second "activated" electrode is the remote electrode **5** that is always "on". Switching a single lead at a time reduces the spurious couplings arising from channel-to-channel penetration of signals in the multiplexer. It also simplifies the device and reduces its cost. The same is true for the input multiplexer **3**. The potential difference detector measures the difference between the selected array electrode and the remote rest electrode **7**. For a given rest electrode, the output multiplexer **2** sequences through all the other electrodes in the compact set while the potential difference detector makes its measurements. Then the rest electrode is switched and the output multiplexer sequence repeated.

Using the two singular electrodes **5**, **7** also increase the amplitude of the measured signals due to the increased distance between the points where the potentials are measured. This increases the signal-to-noise ratio and the accuracy of the measurements. The distance of these singular electrodes from the electrode array allows one to assume that the unperturbed equipotential surfaces of electric field are spherical in the examination area. It simplifies and speeds up the conductivity reconstruction calculations.

The method of back projection along equipotential surfaces of the electric field is used to reconstruct the 3-D conductivity distribution. It is assumed that in the case where the electric current is injected through one of the electrodes of the compact set of electrodes arranged in a planar array and the remote common electrode, equipotential surfaces near the two-dimensional set of electrodes are spherical. The procedure of back projection is reduced to the following. For some point with coordinates (X, Y, Z) inside the object under visualization, the distance is determined between this point and the injecting electrode of the compact array. This distance is equal to the radius r of the equipotential surface containing the point where the conductivity is reconstructed. Knowing this radius, it is possible to determine the line of intersection of the equipotential surface with the surface on which the electrodes are arranged. When the electrodes are arranged on the plane, given by equation $z=0$, this line is the circle lying in the (x, y) plane having its center at the point where the injecting electrode is located, and having radius r. Conductivity S (in arbitrary units) at the chosen point is calculated according to the equation:

$$S(x,y,z) = 1 + W_1(z)\sum_i \frac{1}{\int_{L(x,y,z,i)} W_2(l)dl} \int_{L(x,y,z,i)} W_2(l)(E_r(l) - E_m(l))/E_r(l)dl$$

where i – is the number of the injecting electrode, $L(x,y,z,i)$ - is the line of intersection of the equipotential surface with the surface on which the electrodes are arranged (circle with radius r). The components of the electric field vector $\vec{E}_m$ are first calculated at the nodes of the grid between the electrodes as the potential differences between adjacent electrodes in the x and y directions. Then these components are linearly interpolated to the current point of integration on the line L and the magnitude of this vector E_m is calculated.

The reference intensity of the electric field E_r corresponds to a homogeneous medium and is calculated numerically. Weighting coefficient $W_1(z)$ corrects the decrease of sensitivity with depth. In the present invention, the empirical equation $W_1 = (z+\alpha)/(z+\beta), \alpha << \beta$ is used for it. The weighting coefficient W_2 provides a relatively greater contribution to the calculated conductivity of those points on line L, which are located closer to the point at which the conductivity is reconstructed. In the present device, the equation: $W_2 = 1/R^4 = 1/\left((x-x_i)^2 + (y-y_i)^2 + z^2\right)^2$ is used, where R is the

distance between the point where the conductivity is reconstructed and the current point on the line along which integration is being carried out; the index *l* refers to the coordinates of this point.

The method of back projection is the fastest method used in electrical impedance tomography reconstruction. Its use, however, for reconstructing the static conductivity distribution for the 3-D case is only possible by a proper choice of the projected values.

In addition, the synthesized reference data set E_r must be used. This is obtained by approximating the real measured potentials according to the method of Korjenevsky. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," Russian Federation patent application N 96123647/14.)

In many cases it is difficult to obtain sufficient contact of all the electrodes with the patient's body. Consequently, the threshold detector **8** of the output voltage is used to determine whether the electrode being measured at any particular moment has sufficient contact with the body. The compact set of electrodes is arranged on a rigid dielectric plane and every electrode is a conducting protrusion from the plane. This arrangement permits an examination of a mammary gland regardless of its size. During an examination, this plane of electrodes is pressed against the breast, flattening it toward the chest. This increases the number of electrodes having contact with the body and decreases the thickness of the tissue layer to be measured. The protrusion of the electrodes improves their electrical contact with the body.

One or more of the electrodes on the periphery of the plane may not have contact with the body, depending on the size of the examined object. These electrodes are detected with the help

of the threshold detector of the output voltage mentioned above. The values of the potential differences measured from electrodes that have insufficient body contact cannot be used directly in the process of conductivity reconstruction. Instead, values of potential differences calculated on the assumption of a homogeneous conductivity distribution are used.

Besides the useful potential differences caused by the current flow, there are also galvanic potential differences between electrodes. The component for measuring the potential difference **6** is only sensitive to the alternating current component and, consequently, is not disturbed by the presence of these constant galvanic potential differences. However, due to the differences in galvanic potentials of different electrodes, the input voltage varies by a jump when the input multiplexer **3** is switched. These jumps produce a transient that influences the results of the measurements. This influence increases when the time interval between the switch and the start of the potential difference measurement decreases. Therefore, to decrease the error while keeping the total duration of the measurements constant, the input multiplexer **3** should switch the device for measuring the potential difference **6** to the next electrode only after the output multiplexer **2** completes the total cycle of switches of the AC source to all other electrodes.

FIG. 2 shows the arrangement of the various components of the electric mammograph used to take measurements. With the help of the output multiplexer, the control unit connects the source of AC current to one of the electrodes of compact set **1** according to commands from the computer **11**. AC current of approximately 1 mA and a frequency of 10 kHz flows through the circuit, i.e., from the AC source to the multiplexer, to the electrode of set **1**, through the patient's body to the remote rest

electrode **5**. With the help of the input multiplexer, the microprocessor connects one of the rest electrodes from set **1** to the potential difference detector. It measures the amplitude of the alternating voltage between the electrode from set **1** and the remote activated electrode **7**. This measurement is sent in digital code to the microprocessor, which passes it to the computer **11**.

The measured data are used to reconstruct a 3-D conductivity distribution with the help of the algorithm shown in block diagram form in FIG. 3. In block **12** the measured potentials of the electrodes from the compact set, received through the connection line **10**, are used for synthesis of the reference set of potentials corresponding to a body with homogeneous conductivity. An approximation by the method of least squares described in Russian Patent N 96123647/14 is used. Only those potentials obtained from electrodes with good body contact are used. In blocks **13** and **14**, components of the electric intensity vector are calculated for the reference and measured data set by subtraction of the values of potentials on adjacent electrodes for each variant of connection of the current source. In the last case, corresponding potentials from the reference set are used instead of the potentials of those electrodes with insufficient contact.

In block **15** the distance is calculated between the activated electrode in the compact set and the point at which the conductivity is being reconstructed. This distance determines the radius of a circle that represents the line of intersection of the equipotential surface with the plane on which the electrodes are arranged and along which it is necessary to carry out weighted averaging. The electric intensity for the measured and the reference data set are calculated after the linear interpolation of the corresponding components of vectors, calculated in blocks **13** and

14. The relative difference of the electric intensities for the reference and measured data sets are multiplied by the weight function $1/R^4$, where R is the distance between the point where the conductivity is reconstructed and the current point on the line along which averaging is being carried out.

In block **16** the obtained value is numerically integrated along the circle. These operations are repeated for all points where the conductivity is to be reconstructed and for all variants of the activated electrodes. This process is controlled by block **17**. The result of these calculations, after adding a unit to obtained values, represents a 3-D distribution of the conductivity normalized on the average value. The result can be displayed on screen or printed out. Block **18** contains the software and hardware used to carry out these functions.

The external appearance of the electric mammograph without the computing unit is shown in FIG. 4. FIG. 5 shows an electric mammogram obtained by the invention. The mammogram represents a set of seven images of breast cross-sections parallel to the plane on which the electrodes are arranged. The depth of the cross-sections increases from left to right and from up to down with 8 mm steps. On the image one can clearly see the nipple 19, the ribs **20**, and the boundary **21** between areas with and without sufficient electrode contact with the body.

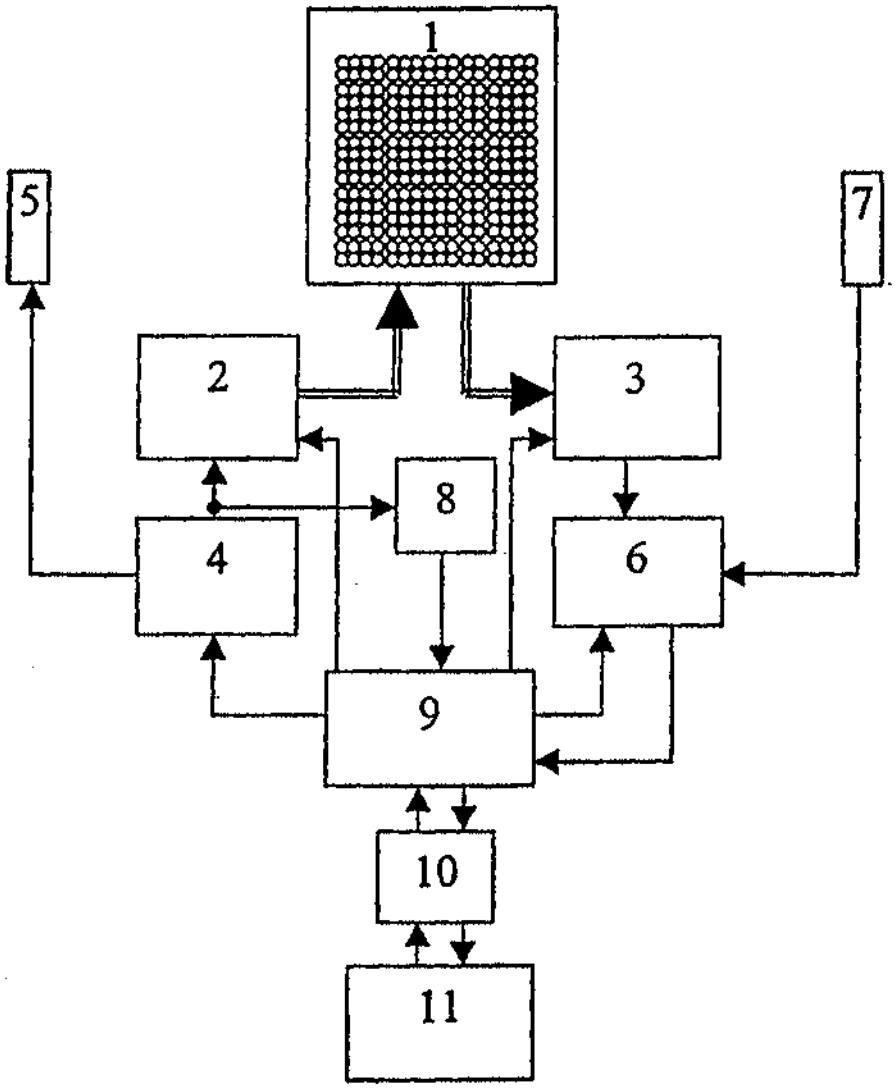


FIG. 1

Electric Mammograph

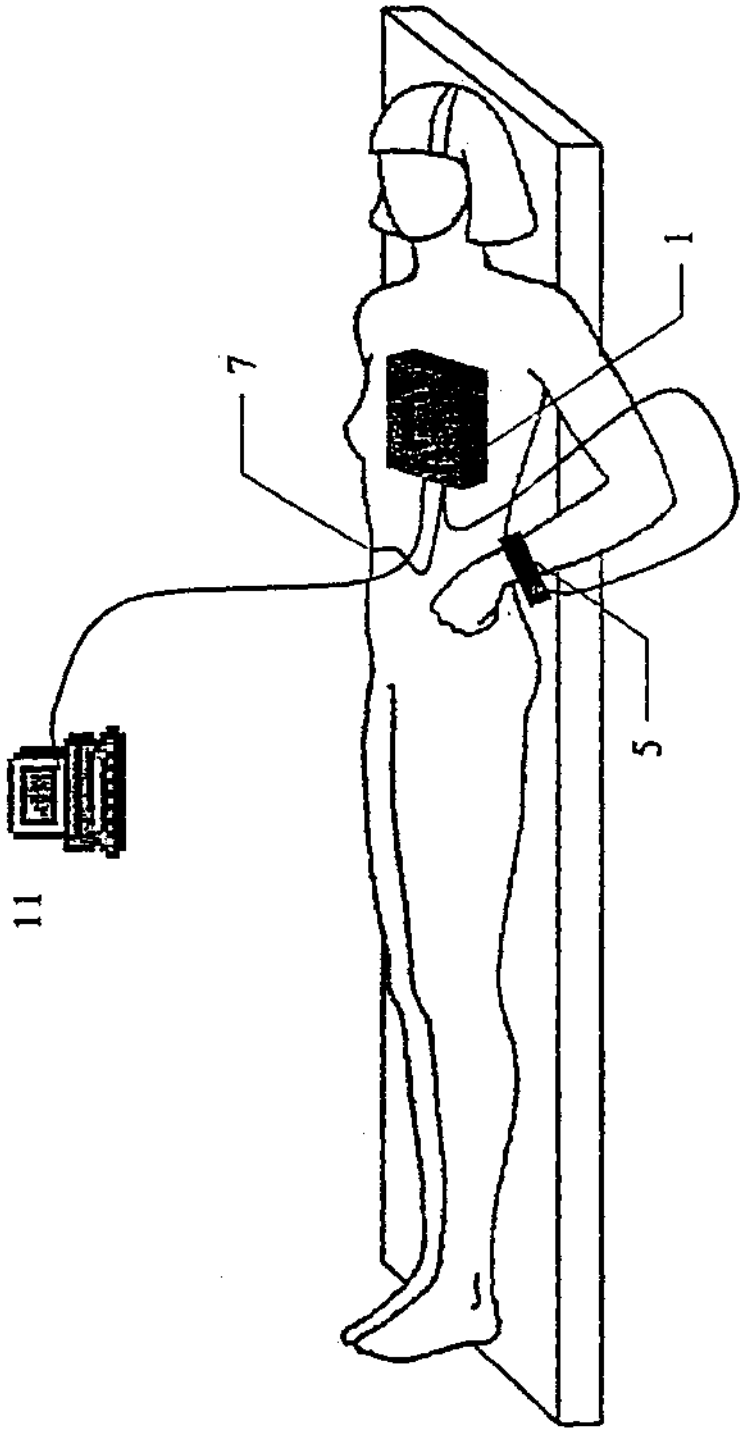


FIG. 2

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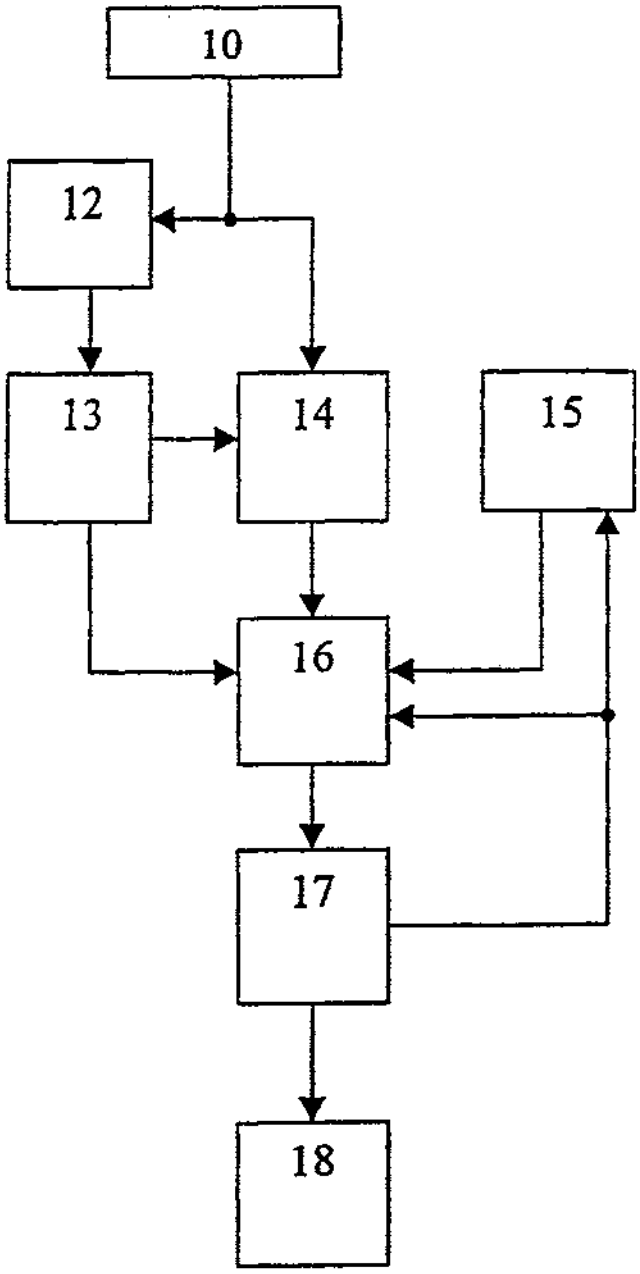


FIG. 3

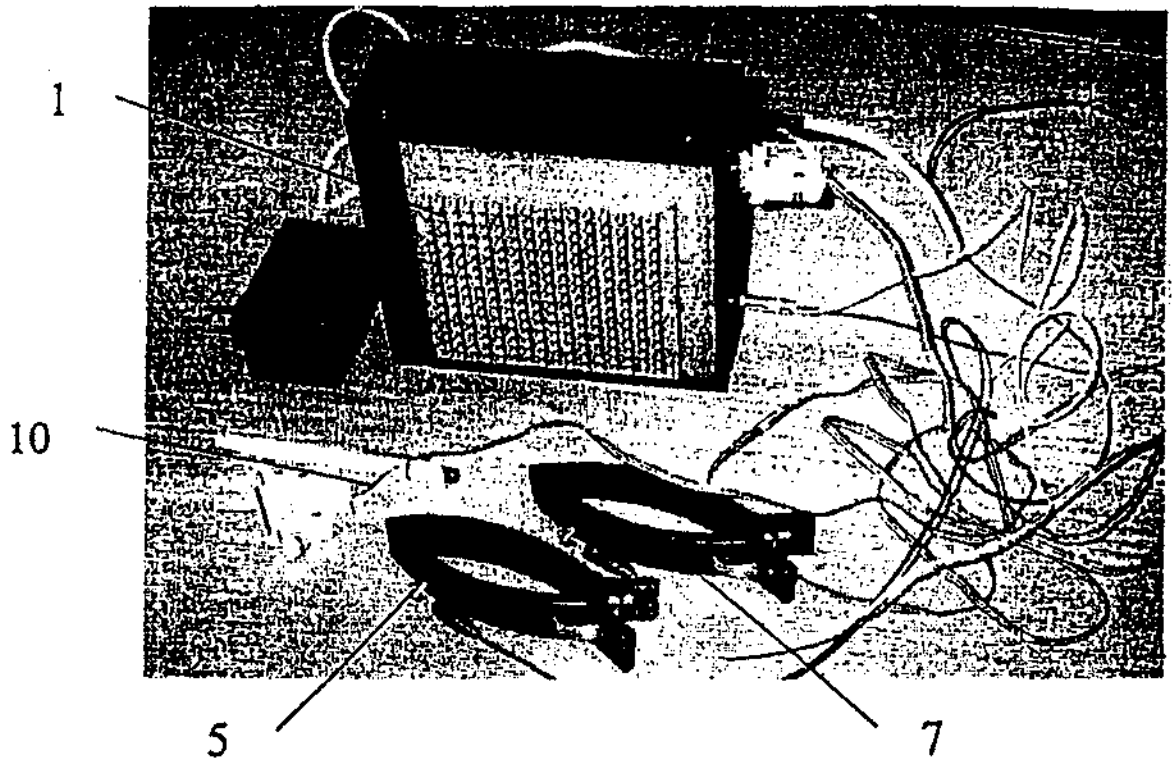


FIG. 4

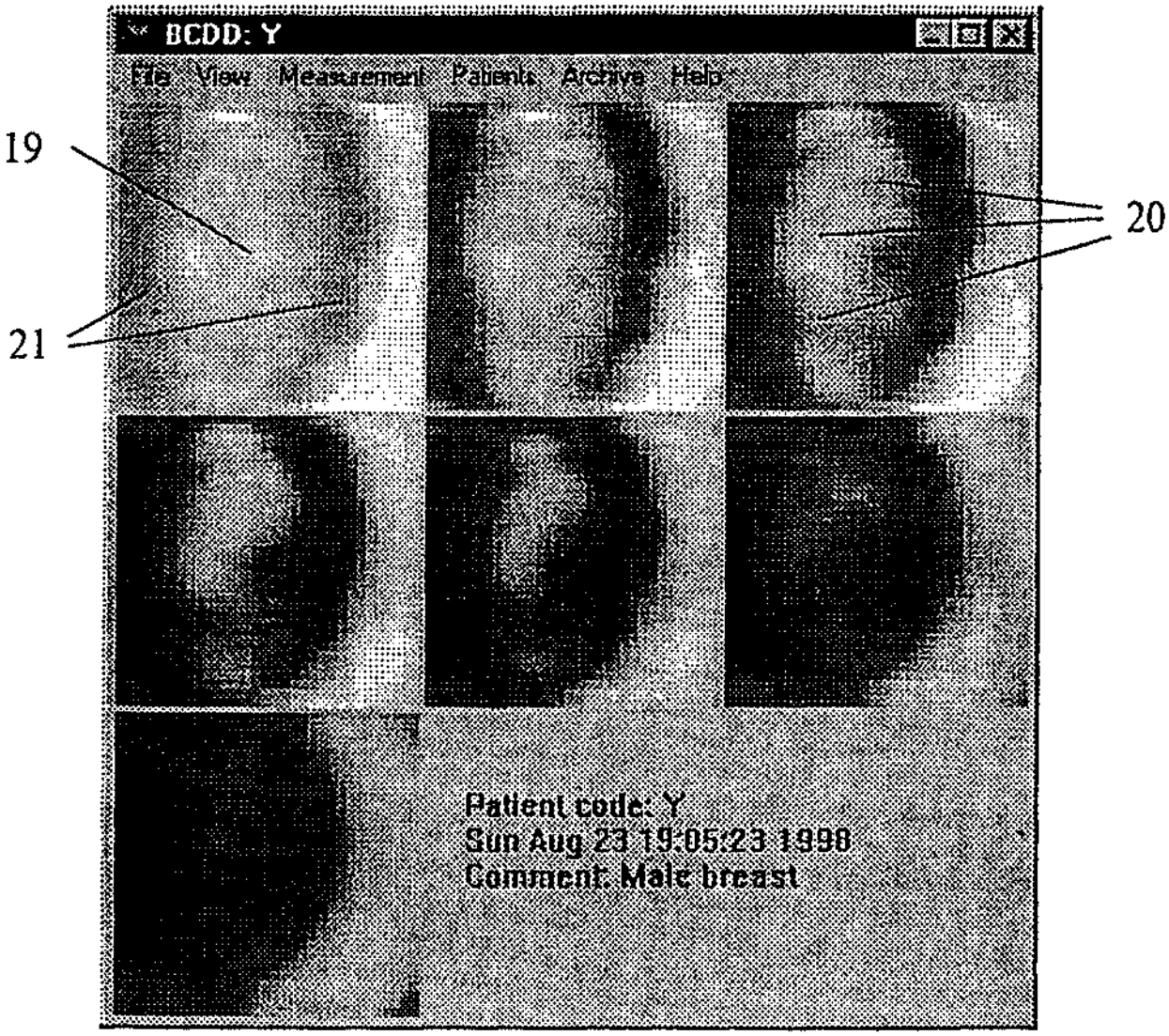
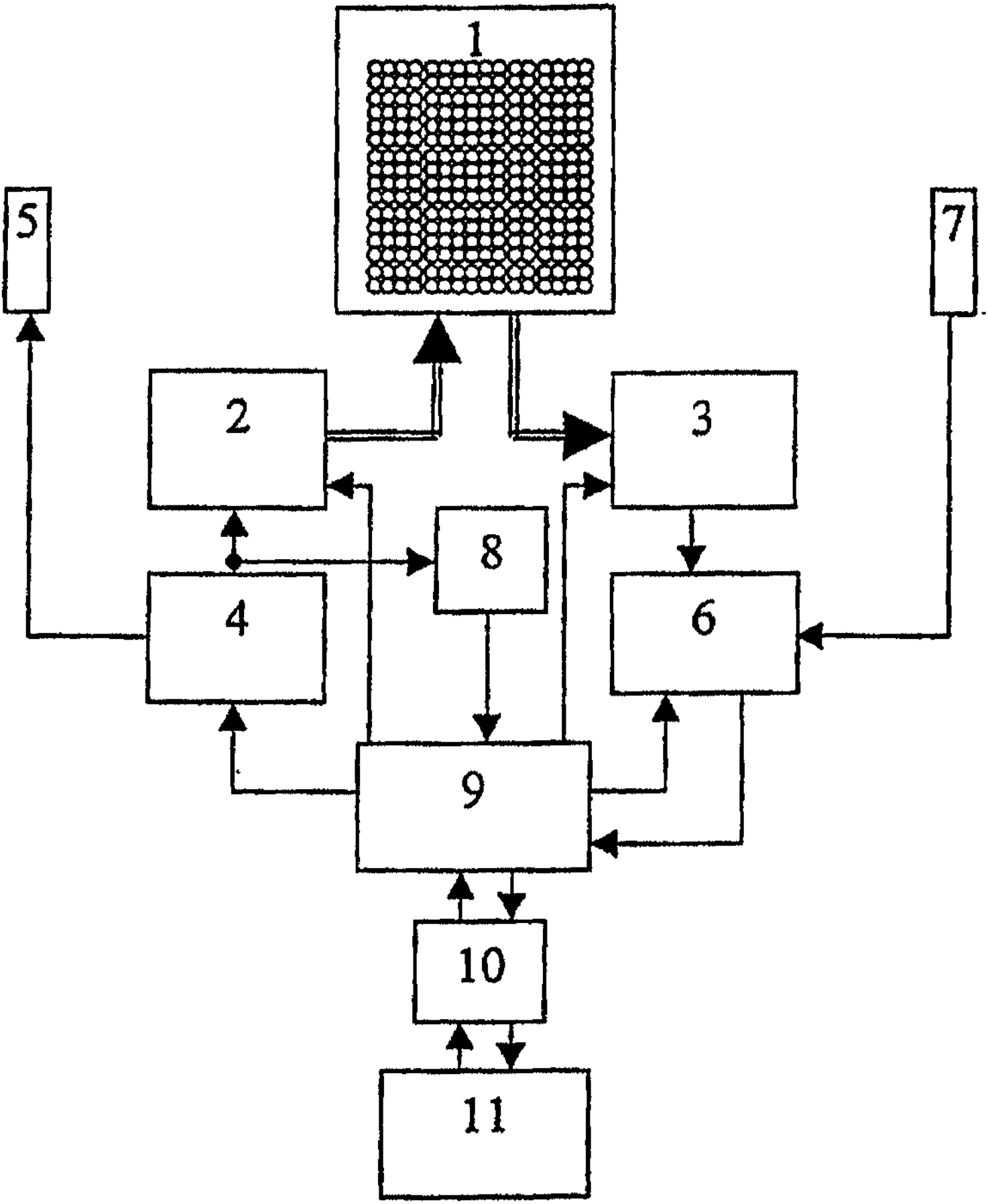

BCDD: Y
File View Measurement Patients Archive Help
19
20
21
Patient code: Y
Sun Aug 23 19:05:23 1998
Comment: Male breast

FIG. 5


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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : A61B 5/05

A1

(11) International Publication Number: WO 00/53090

(43) International Publication Date: 14 September 2000 (14.09.00)

(21) International Application Number: PCT/US00/06283

(22) International Filing Date: 8 March 2000 (08.03.00)

(30) Priority Data:
09/264,594 8 March 1999 (08.03.99) US

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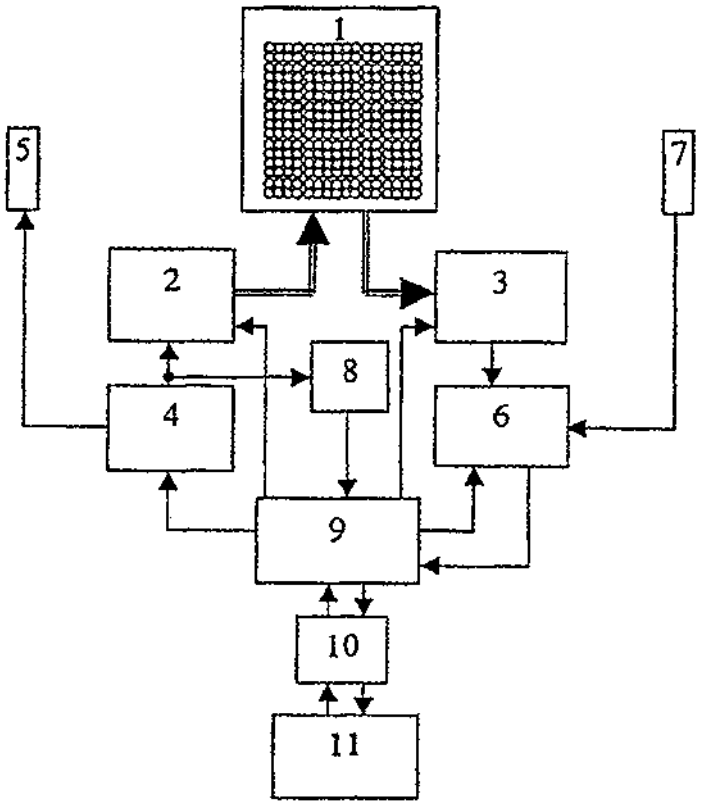
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: ELECTRIC MAMMOGRAPH

(57) Abstract

The electric mammograph is an electrical impedance tomograph device for obtaining three–dimensional images of the conductivity distribution in biological tissues. A planar array of electrodes (1) is put in contact with the tissues of interest. An AC source (4) is connected to a single remotely attached electrode (5, 7) and to one of the planar array electrodes (1). Potential differences between the at rest electrodes in the planar array and a second remote at rest electrode (7, 5) are measured. The images are reconstructed using a modified back projection method.



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ELECTRIC MAMMOGRAPH

Technical Field

The invention is in the field of medical tomography, and in particular relates to a method and apparatus for the visualization and diagnosis of pathologic changes in breast tissues and other organs near the surface of the human body.

Background Art

It is known that electrical conductivity of many tumors, and in particular the malignant tumors of the mammary gland, significantly differs from the conductivity of surrounding sound tissues. This fact may be used for the detection and localization of such tumors.

Some devices are known for visualizing the spatial distribution of conductivity (impedance) in the human body, e.g., electrical impedance tomographs. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," International application PCT/RU97/00398.) In an electrical impedance tomograph, the source of alternating electric current is connected to pairs of electrodes placed along a line on the surface of a body and measurements of the potential differences are made on the other pairs of electrodes. The results of measurements obtained from various combinations of electrodes are used to reconstruct the conductivity distribution with the help of a computer. A three-dimensional distribution of conductivity, however, is not possible with this type of tomograph. Furthermore, its resolution falls significantly from the periphery to the center of contour of the electrodes. Consequently, it is not an adequate device for the diagnosis of mammary gland tumors.

An electroimpedance mammograph device, purporting

to yield a three-dimensional impedance distribution has also been described. (A. Nowakovsky, J. Wortek, and J. Stelter, "A Technical University of Gdansk Electroimpedance Mammograph," Proc. IX Int. Conf. Electrical Bio-Impedance, Heidelberg, 1995, p. 434-437; J. Wortek, J. Stelter, A. Nowakovsky, "Impedance mammograph 3D phantom studies," Proc. X Int. Conf. Electrical Bio-Impedance, Barcelona, 1998, p. 521-524.) This device contains a compact set of electrodes that are placed on the inner surface of a rigid hemisphere, multiplexers that are connected to the source of alternating electric current, and a device for measuring the potential difference between various pairs of electrodes. The measured potential differences are sent to a computer to reconstruct and display the three-dimensional impedance distribution inside the hemisphere. The serviceability of this device based on actual measurements on the human body have not yet been published.

A number of limitations for this device are apparent. The arrangement of electrodes on the hemisphere surface limits the application of the device because the contact with all the electrodes can be provided only for a breast of a definite size. The device also has no means to measure the quality of each contact, nor any means to correct the reconstruction calculations if any of the electrodes have insufficient contact with the body. This decreases the validity of the data. The electric current source and the measuring device are connected to pairs of electrodes placed on the hemisphere, requiring four multiplexers. When the number of electrodes is large, these multiplexers become the most complicated and expensive parts of the device. These multiplexers are also the largest source of spurious signals due to channel-to-channel crosstalk. Only 64 electrodes were used in the prototype. This is obviously insufficient for obtaining satisfactory resolution.

However, further increasing this number is problematical because of the difficulty of commutation by the chosen measuring circuit.

When a safe level of electrical current is used, the measured potential differences are small because of the small distances between electrodes. This decreases the signal-to-noise ratio and the display quality. This effect only gets worse with an increasing number of electrodes. The algorithm for image reconstruction is based on the perturbation method. It requires a calculation time of ten minutes on a workstation for a system of 64 electrodes (Nowakovsky). For 180 electrodes, the minimum necessary for practical applications, about ten hours are required for the calculations based on the estimations of the authors. This amount of time is not feasible for clinical practice.

Other attempts at obtaining three-dimensional electrical impedance images of a body have involved multi-dimensional electrode arrays that surround or partially surround the object being imaged. The reconstruction algorithms used and the methodology of making measurements were also different than those of the present invention. These efforts include U. S. Patents 5,284,142, 5,351,697, 4,263,920, 4,486,835, and 4,539,640.

A goal of the present invention is to provide a new method and apparatus for electric mammography with greater reliability and accuracy of measurements, higher resolution, and increased computational speed. This invention is particularly applicable to the clinical diagnosis of breast tumors and other subsurface areas.

Disclosure of the Invention

The electric mammograph is a device for the measurement and three-dimensional (3-D) reconstruction of the conductivity distribution in biological tissues for clinical diagnoses.

It consists of a compact array of electrodes positioned over the tissue being measured, two additional electrodes spaced apart from the array of electrodes, a source of alternating (AC) current, a means to measure potential difference, and computing means to reconstruct and visualize the resulting conductivity distribution.

Brief Description of the Drawings

The invention is illustrated in the following drawings.

FIG. 1 is a block diagram of the electric mammograph.

FIG. 2 shows the arrangement of the apparatus when conducting a mammograph examination.

FIG. 3 is a block diagram of the algorithm used for the three-dimensional conductivity distribution reconstruction.

FIG. 4 is a photograph of the apparatus

FIG. 5 is a sample electric mammogram.

Description of Preferred Embodiments

A block diagram of the components of the electric mammograph is shown in FIG. 1. A compact array of cylindrical protruding electrodes **1** is arranged in a rigid dielectric plane. The example shown has 256 electrodes. The output multiplexer **2** is connected to the electrode array **1** and is the means by which the alternating current (AC) source **4** is connected to one of the cylindrical electrodes in the array. The input multiplexer **3** serves to connect one of the non-activated or "rest" electrodes of the array to the potential difference measuring unit **6**. The microprocessor **9** and the computer **11,** connected via cables **10,** determine which electrode is activated and which of the rest electrodes is being measured at any given time.

Two single remote electrodes, **5** and **7**, are attached to the extremities of the patient. One remote electrode **5** is connected directly to the AC source. The other remote electrode **7**

is connected directly to the potential difference detector **6**. The AC source is connected to a voltage threshold detector **8**. The operation of the electric mammograph is controlled by a microprocessor/computer means. It gets inputs from the potential difference detector **6** and the threshold detector **8** and outputs to the two multiplexers **2**, **3**, the potential difference detector, and the AC source. The first remote electrode **5** connected to the AC source and the second remote electrode **7** are located on a patient's extremities, e.g., one on each wrist as shown in FIG. 2.

In the prior art methods of obtaining a tomographic image of a human body, a series of contact electrodes were placed on the surface of the patent's body. A source of electric current was connected sequentially to pairs of electrodes causing current to flow through the body. Measurements were then made of potential differences between pairs of other "non-activated" electrodes.

In the present invention, the output multiplexer **2** switches a single lead from the AC source to "activate" a single electrode in the electrode array **1** at a time, instead of activating pairs of electrodes in prior art devices. The second "activated" electrode is the remote electrode **5** that is always "on". Switching a single lead at a time reduces the spurious couplings arising from channel-to-channel penetration of signals in the multiplexer. It also simplifies the device and reduces its cost. The same is true for the input multiplexer **3**. The potential difference detector measures the difference between the selected array electrode and the remote rest electrode **7**. For a given rest electrode, the output multiplexer **2** sequences through all the other electrodes in the compact set while the potential difference detector makes its measurements. Then the rest electrode is switched and the output multiplexer sequence repeated.

Using the two singular electrodes **5**, **7** also increase the amplitude of the measured signals due to the increased distance between the points where the potentials are measured. This increases the signal-to-noise ratio and the accuracy of the measurements. The distance of these singular electrodes from the electrode array allows one to assume that the unperturbed equipotential surfaces of electric field are spherical in the examination area. It simplifies and speeds up the conductivity reconstruction calculations.

The method of back projection along equipotential surfaces of the electric field is used to reconstruct the 3-D conductivity distribution. It is assumed that in the case where the electric current is injected through one of the electrodes of the compact set of electrodes arranged in a planar array and the remote common electrode, equipotential surfaces near the two-dimensional set of electrodes are spherical. The procedure of back projection is reduced to the following. For some point with coordinates (X, Y, Z) inside the object under visualization, the distance is determined between this point and the injecting electrode of the compact array. This distance is equal to the radius r of the equipotential surface containing the point where the conductivity is reconstructed. Knowing this radius, it is possible to determine the line of intersection of the equipotential surface with the surface on which the electrodes are arranged. When the electrodes are arranged on the plane, given by equation $z=0$, this line is the circle lying in the (x, y) plane having its center at the point where the injecting electrode is located, and having radius r. Conductivity S (in arbitrary units) at the chosen point is calculated according to the equation:

$$S(x,y,z) = 1 + W_1(z)\sum_i \frac{1}{\int_{l(x,y,z,i)} W_2(l)dl} \int_{L(x,y,z,i)} W_2(l)(E_r(l) - E_m(l))/E_r(l)dl$$

where i – is the number of the injecting electrode, $L(x,y,z,i)$ - is the line of intersection of the equipotential surface with the surface on which the electrodes are arranged (circle with radius r). The components of the electric field vector $\bar{E}_m$ are first calculated at the nodes of the grid between the electrodes as the potential differences between adjacent electrodes in the x and y directions. Then these components are linearly interpolated to the current point of integration on the line L and the magnitude of this vector E_m is calculated.

The reference intensity of the electric field E_r corresponds to a homogeneous medium and is calculated numerically. Weighting coefficient $W_1(z)$ corrects the decrease of sensitivity with depth. In the present invention, the empirical equation $W_1 = (z+\alpha)/(z+\beta), \alpha << \beta$ is used for it. The weighting coefficient W_2 provides a relatively greater contribution to the calculated conductivity of those points on line L, which are located closer to the point at which the conductivity is reconstructed. In the present device, the equation: $W_2 = 1/R^4 = 1/\left((x-x_l)^2 + (y-y_l)^2 + z^2\right)^2$ is used, where R is the

distance between the point where the conductivity is reconstructed and the current point on the line along which integration is being carried out; the index *l* refers to the coordinates of this point.

The method of back projection is the fastest method used in electrical impedance tomography reconstruction. Its use, however, for reconstructing the static conductivity distribution for the 3-D case is only possible by a proper choice of the projected values.

In addition, the synthesized reference data set E_r must be used. This is obtained by approximating the real measured potentials according to the method of Korjenevsky. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph," Russian Federation patent application N 96123647/14.)

In many cases it is difficult to obtain sufficient contact of all the electrodes with the patient's body. Consequently, the threshold detector **8** of the output voltage is used to determine whether the electrode being measured at any particular moment has sufficient contact with the body. The compact set of electrodes is arranged on a rigid dielectric plane and every electrode is a conducting protrusion from the plane. This arrangement permits an examination of a mammary gland regardless of its size. During an examination, this plane of electrodes is pressed against the breast, flattening it toward the chest. This increases the number of electrodes having contact with the body and decreases the thickness of the tissue layer to be measured. The protrusion of the electrodes improves their electrical contact with the body.

One or more of the electrodes on the periphery of the plane may not have contact with the body, depending on the size of the examined object. These electrodes are detected with the help

of the threshold detector of the output voltage mentioned above. The values of the potential differences measured from electrodes that have insufficient body contact cannot be used directly in the process of conductivity reconstruction. Instead, values of potential differences calculated on the assumption of a homogeneous conductivity distribution are used.

Besides the useful potential differences caused by the current flow, there are also galvanic potential differences between electrodes. The component for measuring the potential difference **6** is only sensitive to the alternating current component and, consequently, is not disturbed by the presence of these constant galvanic potential differences. However, due to the differences in galvanic potentials of different electrodes, the input voltage varies by a jump when the input multiplexer **3** is switched. These jumps produce a transient that influences the results of the measurements. This influence increases when the time interval between the switch and the start of the potential difference measurement decreases. Therefore, to decrease the error while keeping the total duration of the measurements constant, the input multiplexer **3** should switch the device for measuring the potential difference **6** to the next electrode only after the output multiplexer **2** completes the total cycle of switches of the AC source to all other electrodes.

FIG. 2 shows the arrangement of the various components of the electric mammograph used to take measurements. With the help of the output multiplexer, the control unit connects the source of AC current to one of the electrodes of compact set **1** according to commands from the computer **11**. AC current of approximately 1 mA and a frequency of 10 kHz flows through the circuit, i.e., from the AC source to the multiplexer, to the electrode of set **1**, through the patient's body to the remote rest

electrode **5**. With the help of the input multiplexer, the microprocessor connects one of the rest electrodes from set **1** to the potential difference detector. It measures the amplitude of the alternating voltage between the electrode from set **1** and the remote activated electrode **7**. This measurement is sent in digital code to the microprocessor, which passes it to the computer **11**.

The measured data are used to reconstruct a 3-D conductivity distribution with the help of the algorithm shown in block diagram form in FIG. 3. In block **12** the measured potentials of the electrodes from the compact set, received through the connection line **10**, are used for synthesis of the reference set of potentials corresponding to a body with homogeneous conductivity. An approximation by the method of least squares described in Russian Patent N 96123647/14 is used. Only those potentials obtained from electrodes with good body contact are used. In blocks **13** and **14**, components of the electric intensity vector are calculated for the reference and measured data set by subtraction of the values of potentials on adjacent electrodes for each variant of connection of the current source. In the last case, corresponding potentials from the reference set are used instead of the potentials of those electrodes with insufficient contact.

In block **15** the distance is calculated between the activated electrode in the compact set and the point at which the conductivity is being reconstructed. This distance determines the radius of a circle that represents the line of intersection of the equipotential surface with the plane on which the electrodes are arranged and along which it is necessary to carry out weighted averaging. The electric intensity for the measured and the reference data set are calculated after the linear interpolation of the corresponding components of vectors, calculated in blocks **13** and

14. The relative difference of the electric intensities for the reference and measured data sets are multiplied by the weight function $1/R^4$, where R is the distance between the point where the conductivity is reconstructed and the current point on the line along which averaging is being carried out.

In block **16** the obtained value is numerically integrated along the circle. These operations are repeated for all points where the conductivity is to be reconstructed and for all variants of the activated electrodes. This process is controlled by block **17**. The result of these calculations, after adding a unit to obtained values, represents a 3-D distribution of the conductivity normalized on the average value. The result can be displayed on screen or printed out. Block **18** contains the software and hardware used to carry out these functions.

The external appearance of the electric mammograph without the computing unit is shown in FIG. 4. FIG. 5 shows an electric mammogram obtained by the invention. The mammogram represents a set of seven images of breast cross-sections parallel to the plane on which the electrodes are arranged. The depth of the cross-sections increases from left to right and from up to down with 8 mm steps. On the image one can clearly see the nipple 19, the ribs **20**, and the boundary **21** between areas with and without sufficient electrode contact with the body.

CLAIMS

1. A method of displaying a three-dimensional image of the conductivity distribution of biological tissue, said method comprising the steps of:

applying a source (4) of alternating current (AC) to a first activated electrode (1) of a compact set of electrodes arranged in a planar array, said compact set of electrodes being in contact with the surface of the biological tissues of interest, and to a first remotely located electrode (5, 7) in contact with the body but at some distance from the compact set of electrodes;

measuring the potential difference between a first at rest electrode (1) of said compact set and a second remotely located electrode (7,5), said second remote electrode being at rest;

switching the source (4) of AC current by multiplexer means (2, 3) to activate successively all of the electrodes (1) of said planar array of electrodes except said at rest electrode of step (b) and measuring the potential difference between said at rest electrodes in (b) for each activated electrode in turn to thereby obtain a first set of potential difference measurements for each activated electrode;

switching the electrode (1) to be measured in said planar array by multiplexer means (2, 3) to a second at rest electrode (1), activating successively every other electrode in said planar array, and measuring the potential difference between said second at rest electrode and said at rest remote electrode (7, 5) in turn to thereby obtain a second set of potential difference measurements for each activated electrode;

continue switching the at rest electrode (1), activating successively the remaining electrodes in said planar array, and measuring the potential difference between the selected at rest

electrode and said at rest remote electrode (7, 5) in turn until all planar electrodes combinations have been measured;

reconstructing a three-dimensional conductivity distribution using the method of back projection along equipotential surfaces of the electric field, the projected data being obtained by weighted averaging of the relative difference between the reference electric intensity corresponding to tissue with a homogeneous conductivity distribution and the measured electric intensity along the line of intersection of the equipotential surface containing the point where conductivity is reconstructed and with the surface on which the compact set of electrodes (1) is located.

2. The method of claim 1, whereby a threshold detector means (8) determines whether any particular electrode (1) of the planar array has sufficient contact with the tissue to give a meaningful measurement.

3. The method of claim 2, whereby the values of potential differences for those electrodes (1) having insufficient contact with the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

4. The method of claim 1, whereby the weighting coefficient of $1/R^4$ is used in the weighted averaging of step (f), where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

5. The method of claim 1, whereby said compact set of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

6. An apparatus for producing a three-dimensional image of the conductivity distribution of biological tissue comprising:

a plurality of individual electrodes (1) disposed in a rigid planar array and placed in contact with the biological tissue of interest;

an alternating current (AC) source (4) connected to one of the electrodes (active electrode) (1) in said planar array and to a single remote active electrode (5, 7) located at some distance from said planar array and in contact with the biological tissue;

an output multiplexing means (2) to successively switch the AC source to other electrodes (1) in said planar array making them active electrodes in turn;

an input multiplexing means (3) to connect a potential difference measuring means (6) to one of the non-active (at rest) electrodes (1) in said planar array and to an at rest single remote electrode (7, 5) located at some distance from said planar array and in contact with the biological tissue;

computing means coupled to said input and output multiplexing means (2, 3) for sequencing said AC source through said planar array electrodes (1) while taking potential difference measurements from other electrodes in said planar array and for reconstructing a three-dimensional conductivity distribution using a modified back projection method; and

display means for imaging the reconstructed three-dimensional conductivity distribution.

7. The apparatus of claim 6, wherein a threshold detector means (8) is provided to determine whether any particular electrode (1) of said planar array has sufficient contact with the tissue to give a meaningful measurement.

8. The apparatus of claim 7, wherein in reconstructing the conductivity distribution, the values of potential differences for those electrodes (1) having insufficient contact with

the tissue are calculated based on the assumption of a homogeneous conductivity distribution rather than using the actual measured potential differences.

9. The apparatus of claim 6, wherein the modified back projection reconstruction method used incorporates a weighting coefficient of $1/R^4$, where R is the distance between the point where the conductivity is being reconstructed and the current point on the line along which averaging is being carried out.

10. The apparatus of claim 6, wherein said planar array of electrodes (1) is arranged on a rigid dielectric plane and the conducting portion of each electrode protrudes from said plane.

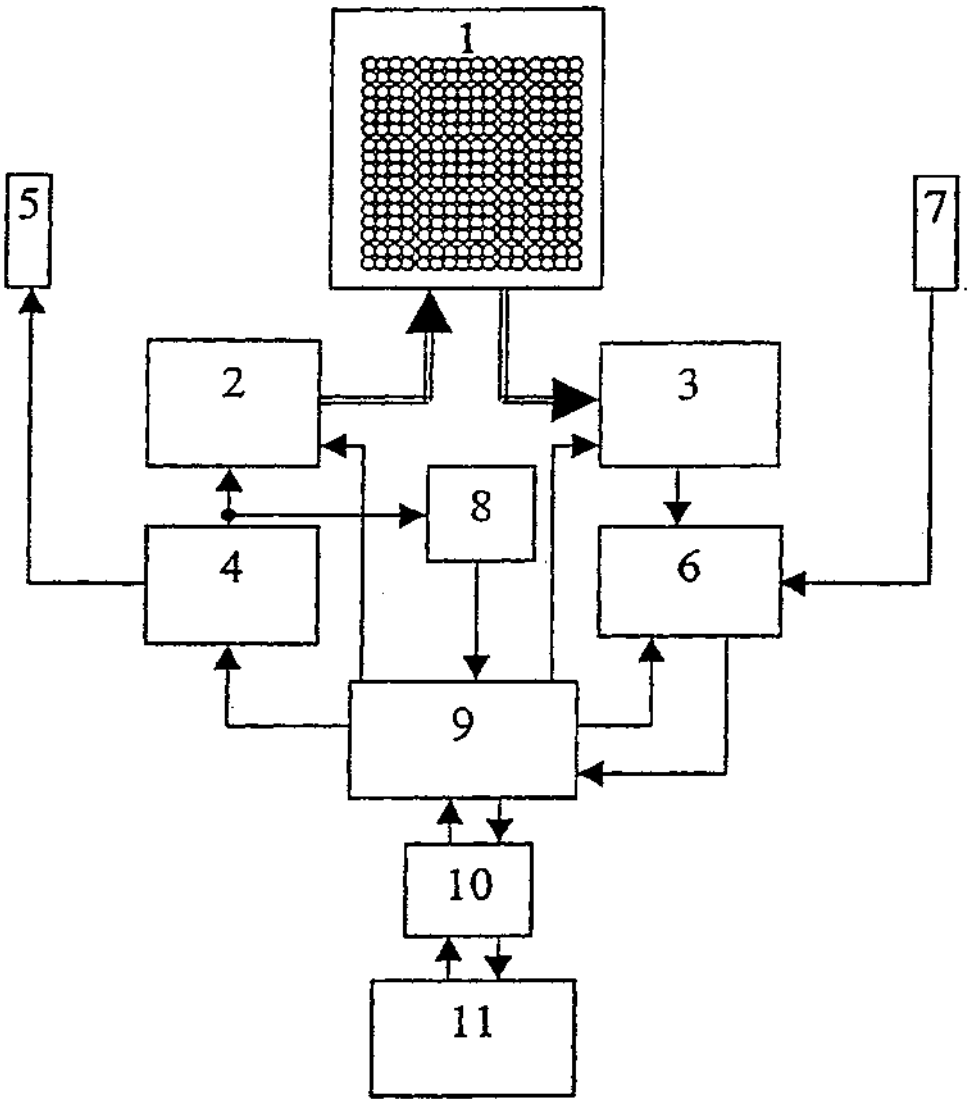


FIG. 1

Electric Mammograph

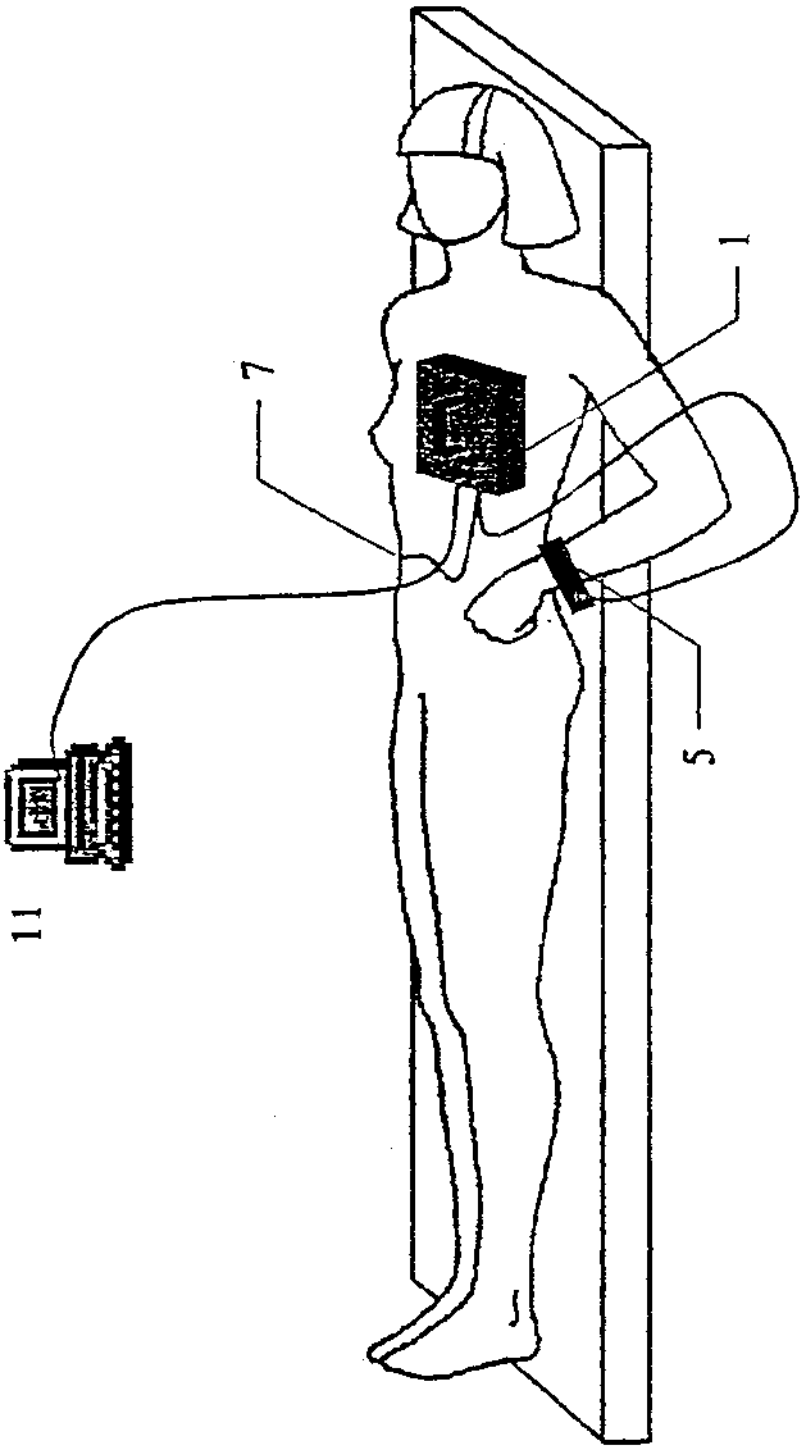


FIG. 2

SHEET 2 of 5

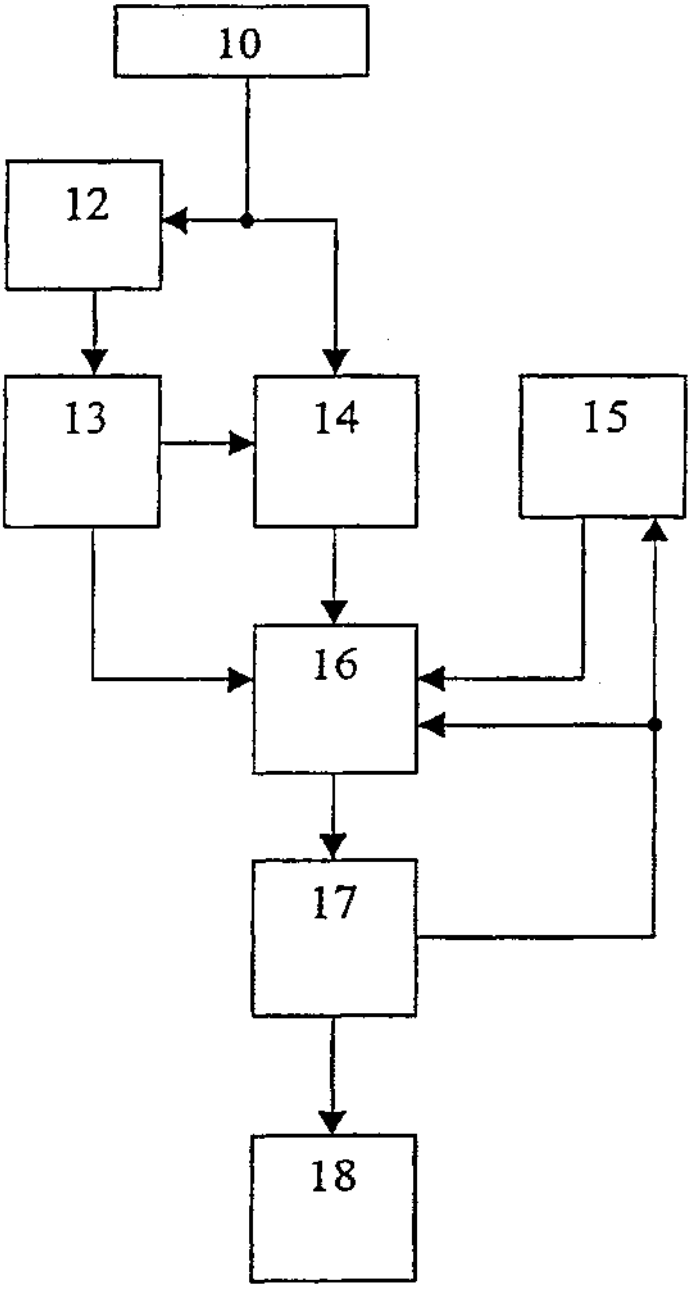


FIG. 3

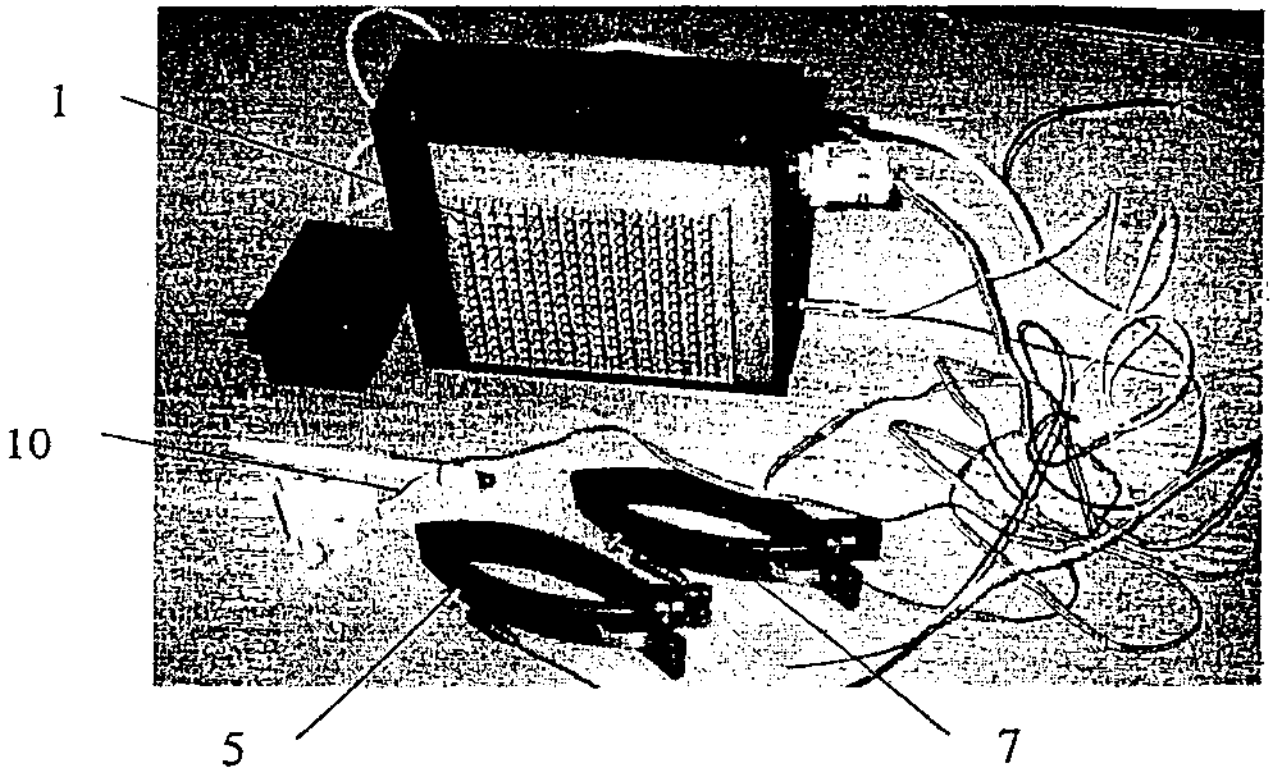


FIG. 4

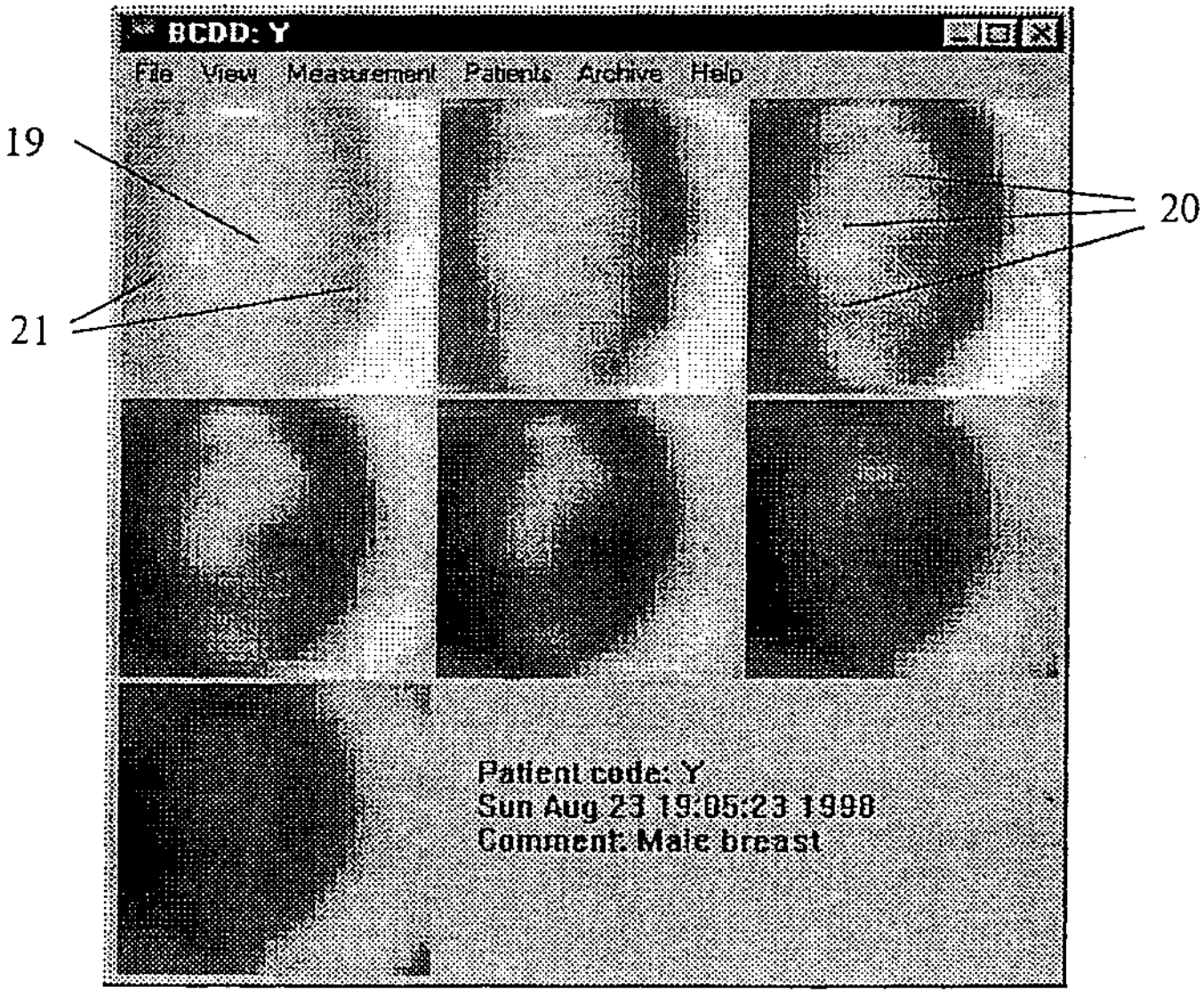

BCDD: Y
File View Measurement Patients Archive Help
19
20
21
Patient code: Y
Sun Aug 23 19:05:23 1998
Comment: Male breast

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/06283

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61B 5/05
US CL :128/930; 324/717; 600/547

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/930; 324/600, 713, 717; 600/547

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,351,697 A (CHENEY et al.) 04 October 1994, Abstract	1, 6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 03 MAY 2000	Date of mailing of the international search report 19 MAY 2000
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Form PCT/ISA/210 (second sheet) (July 1998)*

(19) Bundesrepublik Deutschland
Deutsches Patent- und Markenamt

(10) **DE 600 17 384 T2** 2006.03.02

(12) # Übersetzung der europäischen Patentschrift

(97) **EP 1 180 967 B1**
(21) Deutsches Aktenzeichen: **600 17 384.4**
(86) PCT-Aktenzeichen: **PCT/US00/06283**
(96) Europäisches Aktenzeichen: **00 917 833.6**
(87) PCT-Veröffentlichungs-Nr.: **WO 00/53090**
(86) PCT-Anmeldetag: **08.03.2000**
(87) Veröffentlichungstag der PCT-Anmeldung: **14.09.2000**
(97) Erstveröffentlichung durch das EPA: **27.02.2002**
(97) Veröffentlichungstag der Patenterteilung beim EPA: **12.01.2005**
(47) Veröffentlichungstag im Patentblatt: **02.03.2006**

(51) Int Cl.[8]: ***A61B 5/05*** (2006.01)

(30) Unionspriorität:
264594 **08.03.1999** **US**

(84) Benannte Vertragsstaaten:
BE, DE, FR, GB, NL

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(54) Bezeichnung: **ELEKTRISCHER MAMMOGRAPH**

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Beschreibung

Gebiet der Technik

[0001] Die Erfindung liegt im Bereich der medizinischen Tomographie, und betrifft insbesondere ein Verfahren und eine Vorrichtung für die Visualisierung und Diagnose pathologischer Veränderungen in Brustgeweben und anderen Organen in der Nähe der Oberfläche des menschlichen Körpers.

Stand der Technik

[0002] Es ist bekannt, dass sich die elektrische Leitfähigkeit vieler Tumore, und insbesondere bösartiger Tumore der Brustdüse, erheblich von der Leitfähigkeit des umgebenden gesunden Gewebes unterscheidet. Diese Tatsache kann für die Erfassung und Lokalisierung derartiger Tumore eingesetzt werden.

[0003] Einige Vorrichtungen sind für die Visualisierung der räumlichen Verteilung der Leitfähigkeit (Impedanz) im menschlichen Körper bekannt, wie z.B. elektrische Impedanz-Tomographen. (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph; Verfahren zum Erhalt eines tomographischen Bildes eines Körpers und elektrischer Impedanz-Tomograph"; Internationale Anmeldung PCT/RU97/00398.) In einem elektrischen Impedanz-Tomographen wird die Wechselstromquelle an Elektrodenpaare angeschlossen, die entlang einer Linie auf der Oberfläche eines Körpers angeordnet werden, und Messungen der Potentialdifferenzen werden an den anderen Elektrodenpaaren durchgeführt. Die aus den unterschiedlichen Elektrodenkombinationen erhaltenen Ergebnisse der Messungen werden für die Rekonstruktion der Verteilung der spezifischen elektrischen Leitfähigkeit mit Hilfe eines Computers verwendet. Eine dreidimensionale Verteilung der spezifischen elektrischen Leitfähigkeit ist jedoch mit diesem Typ von Tomographen nicht möglich. Weiter fällt seine Auflösung vom Umfang bis zur Mitte des Elektrodenumrisses erheblich ab. Folglich ist dieser Tomograph keine geeignete Vorrichtung für die Diagnose von Brustdüsen-Tumoren.

[0004] Eine Elektroimpedanz-Mammographvorrichtung, welche eine dreidimensionale Impedanzverteilung erreichen soll, wurde ebenfalls beschrieben. (A. Nowakovsky, J. Wortek, und J. Stelter, "A Technical University of Gdansk Electroimpedance Mammograph; Ein Elektroimpedanz-Mammograph der Technischen Universität von Gdansk," Proc. IX Int. Conf. Elektrische Bio-Impedanz, Heidelberg, 1995, Seiten 434–437; J. Wortek, J. Stelter, A. Nowakovsky, "Impedance mammograph 3D phantom studies; Impedanz-Mammograph 3D-Phantomstudien," Proc. X Int. Conf. Elektrische Bio-Impedannz, Barcelona, 1998, Seiten 521–524.) Diese Vorrichtung enthält einen kompakten Elektrodensatz, der auf der Innenfläche einer starren Halbkugel angeordnet ist, Multiplexer, die an die Wechelstromquelle angeschlossen sind, und eine Vorrichtung zum Messen der Potentialdifferenz zwischen verschiedenen Elektrodenpaaren. Die gemessenen Potentialdifferenzen werden an einen Computer zur Rekonstruktion und Anzeige der dreidimensionalen Impedanzverteilung im Inneren der Halbkugel gesendet. Die Tauglichkeit dieser Vorrichtung basierend auf tatsächlichen Messungen am menschlichen Körper ist noch nicht veröffentlicht worden.

[0005] Eine Reihe von Einschränkungen dieser Vorrichtung sind offensichtlich. Die Anordnung der Elektroden auf der Oberfläche der Halbkugel schränkt die Anwendung der Vorrichtung ein, da der Kontakt mit allen Elektroden nur für eine Brust mit einer bestimmten Größe geschaffen werden kann. Die Vorrichtung hat zudem weder eine Vorrichtung zur Messung der Qualität eines jeden Kontakts, noch jegliche Vorrichtung zur Korrektur der Rekonstruktionsberechnungen, falls eine der Elektroden einen unzureichenden Kontakt mit dem Körper aufweist. Dies vermindert die Gültigkeit der Daten. Die elektrische Stromquelle und die Messvorrichtung sind mit Elektrodenpaaren verbunden, die auf der Halbkugel angeordnet sind, und erfordern vier Multiplexer. Wenn die Anzahl der Elektroden groß ist, werden diese Multiplexer zu den kompliziertesten und teuersten Bauteilen der Vorrichtung. Diese Multiplexer sind zudem die größte Quelle innerer Störsignale aufgrund von Nebensprechen von Kanal zu Kanal. Nur 64 Elektroden wurden in dem Prototypen verwendet. Dies ist für den Erhalt einer zufriedenstellenden Auflösung offensichtlich nicht ausreichend. Eine weitere Erhöhung der Anzahl der Elektroden ist jedoch aufgrund der Schwierigkeit bei der Kommutierung durch den gewählten Messschaltkreis problematisch.

[0006] Wenn ein sicherer elektrischer Strompegel eingesetzt wird, sind die gemessenen Potentialdifferenzen gering, da zwischen den Elektroden nur kleine Entfernungen vorliegen. Dadurch werden der Rauschabstand und die Anzeigequalität verringert. Dieser Effekt verschlimmert sich mit zunehmender Anzahl an Elektroden nur. Der Algorithmus für die Rekonstruktion eines Bildes beruht auf der Störungsmethode. Er benötigt eine Berechnungszeit von zehn Minuten und einen Arbeitsplatz für ein System mit 64 Elektroden (Nowakovsky). Für

180 Elektroden, die notwendige Mindestanzahl für praktische Anwendungen, sind basierend auf den Schätzungen der Autoren ungefähr zehn Stunden für die Berechnungen erforderlich. Diese Zeitdauer ist in der klinischen Praxis nicht durchführbar.

[0007] Andere Versuche zum Erhalt dreidimensionaler elektrischer Impedanzbilder eines Körpers machten mehrdimensionale Elektrodengruppierungen notwendig, die das betrachtete Objekt umgeben oder teilweise umgeben. Die verwendeten Rekonstruktionsalgorithmen und die Methodenlehre zur Durchführung von Messungen unterschieden sich ebenfalls von denen der vorliegenden Erfindung. Diese Bemühungen schließen die US-Patente 5,284,142, 5,351,697, 4,263,920, 4,486,835, 4,539,640 und 5,810,742 ein.

[0008] Es ist ein Ziel der vorliegenden Erfindung, ein neues Verfahren und eine neue Vorrichtung zur elektrischen Mammogaphie zu schaffen, die eine größere Zuverlässigkeit und Genauigkeit der Messungen, eine höhere Auflösung und eine verbesserte Rechengeschwindigkeit aufweist. Diese Erfindung ist besonders bei der klinischen Diagnose von Brusttumoren und anderen Bereichen unter der Haut anwendbar.

Offenbarung der Erfindung

[0009] Der elektrische Mammograph ist eine Vorrichtung für die Messung und die dreidimensionale (3-D) Rekonstruktion der Verteilung der spezifischen elektrischen Leitfähigkeit in biologischen Geweben für klinische Diagnosen. Er weist einen kompakten Elektrodensatz, der über dem zu messenden Gewebe angeordnet ist, zwei zusätzliche Elektroden, die beabstandet von dem Elektrodensatz angeordnet sind, eine Vorrichtung zum Messen der Potentialdifferenz, und eine Berechnungsvorrichtung zur Rekonstruktion und Visualisierung der resultierenden Verteilung der spezifischen elektrischen Leitfähigkeit auf.

[0010] Weitere Einzelheiten, Vorteile und Merkmale ergeben sich aus der nachfolgenen Kurzbeschreibung der Erfindung anhand der Zeichnungen.

KURZBESCHREIBUNG DER ZEICHNUNGEN

[0011] Es zeigen:

[0012] Fig. 1 ein Blockdiagramm des elektrischen Mammographen;

[0013] Fig. 2 die Anordnung der Vorrichtung, wenn eine mammographische Untersuchung durchgeführt wird;

[0014] Fig. 3 ein Blockdiagramm des Algorithmus, der für die dreidimensionale Rekonstruktion der Verteilung der spezifischen elektrischen Leitfähigkeit verwendet wird;

[0015] Fig. 4 eine Fotografie der Vorrichtung; und

[0016] Fig. 5 ein Muster eines elektrischen Mammogramms.

BESCHREIBUNG DER BEVORZUGTEN AUSFÜHRUNGSFORMEN

[0017] Ein Blockdiagramm der Bauteile des elektrischen Mammographen ist in Fig. 1 gezeigt. Ein kompakter Satz zylindrischer vorstehender Elektroden **1** ist in einer starren dielektrischen Ebene angeordnet. Das gezeigte Beispiel weist 256 Elektroden auf. Der Ausgabe-Multiplexer **2** ist mit dem Elektrodensatz **1** verbunden und ist die Vorrichtung, über die die Wechselstromquelle (AC) **4** mit einer der zylindrischen Elektroden in dem Satz verbunden ist. Der Eingabe-Multiplexer **3** dient dazu, eine der nicht aktivierten oder "Ruhe"-Elektroden des Satzes mit der Potentialdifferenz-Messeinheit **6** zu verbinden. Der Mikroprozessor **9** und der Computer **11**, die über Kabel **10** verbunden sind, bestimmen, welche Elektrode aktiviert wird und welche der Ruheelektroden zu jedem beliebigen Zeitpunkt gemessen wird.

[0018] Zwei einzelne entfernt angeordnete Elektroden **5** und **7** sind an den Gliedmaßen des Patienten angebracht. Eine entfernt angeordnete Elektrode **5** ist direkt mit der Wechselstromquelle verbunden. Die andere entfernt angeordnete Elektrode **7** ist direkt mit dem Potentialdifferenz-Detektor **6** verbunden. Die Wechselstromquelle ist mit einem Spannungsschwellen-Detektor **8** verbunden. Der Betrieb des elektrischen Mammographen wird von einer Mikroprozessor-/Computervorrichtung gesteuert. Diese erhält Eingangssignale vom Potentialdifferenz-Detektor **6** und dem Schwellenwert-Detektor **8**, und gibt Ausgangssignale an die beiden Multiplexer **2**, **3**, den Potentialdifferenz-Detektor und die Wechselstromquelle aus. Die erste mit der Wechselstrom-

quelle verbundene entfernt angeordnete Elektrode **5** und die zweite entfernt angeordnete Elektrode **7** sind auf Gliedmaßen des Patienten angeordnet, wie z.B. in Fig. 2 gezeigt eine auf jedem Handgelenk.

[0019] Bei den Verfahren des Standes der Technik zum Erhalt eines tomographischen Bildes eines menschlichen Körpers wurde eine Reihe von Kontaktelektroden auf der Oberfläche des Körper des Patienten angeordnet. Eine elektrische Stromquelle wurde nacheinander an Elektrodenpaare angeschlossen, wodurch ein Stromfluss durch den Körper verursacht wurde. Dann wurden Messungen der Potentialdifferenzen zwischen Paaren anderer "nicht aktivierter" Elektroden durchgeführt.

[0020] Bei der vorliegenden Erfindung schaltet der Ausgabe-Multiplexer **2** im Unterschied zu Vorrichtungen des Standes der Technik, bei denen Ekeltrodenpaare aktiviert wurden, eine einzelne Leitung von der Wechselstromquelle, um eine einzelne Elektrode in dem Elektrodensatz **1** zu einem Zeitpunkt zu "aktivieren". Die zweite "aktivierte" Elektrode ist die entfernt angeordnete Elektrode **5**, die immer "eingeschaltet" ist. Das Schalten einer einzelnen Leitung zu einem Zeitpunkt verringert die Störkupplungen, die durch die Durchdringung von Signalen in dem Multiplexer von Kanal zu Kanal entstehen. Es vereinfacht zudem die Vorrichtung und verringert ihre Kosten. Das Selbe gilbt für den Eingabe-Multiplexer **3**. Der Potentialdifferenz-Detektor misst die Differenz zwischen der aus dem Satz ausgewählten Elektrode und der entfernt angeordneten Ruhe-Elektrode **7**. Bei einer vorgegebenen Ruheelektrode ordnet der Ausgabe-Multiplexer **2** alle anderen Elektroden in der kompakten Anordnung sequentiell, während der Potentialdifferenz-Detektor seine Messungen durchführt. Dann wird die Ruheelektrode geschaltet und die Ausgabe-Mutiplexer-Reihenfolge wiederholt.

[0021] Die Verwendung der beiden einzelnen Elektroden **5**, **7** erhöht zudem die Amplitude der gemessenen Signale aufgrund der größeren Entfernung zwischen den Punkten, an denen die Potentiale gemessen werden. Dadurch werden der Rauschabstand und die Genauigkeit der Messungen erhöht. Die Entfernung der einzelnen Elektroden von dem Elektrodensatz erlaubt die Annahme, dass die ungestörten Äquipotentialflächen des elektrischen Feldes im Untersuchungsbereich kugelförmig ausgebildet sind. Dies vereinfacht und beschleunigt die Berechnungen der Rekonstruktion der spezifischen elektrischen Leitfähigkeit.

[0022] Das Verfahren der Rückwärtsprojektion entlang von Äquipotentialflächen des elektrischen Feldes wird zur Rekonstruktion der 3-D Verteilung der spezifischen elektrischen Leitfähigkeit eingesetzt. Es wird davon ausgegangen, dass in dem Fall, dass der elektrische Strom durch eine der Elektroden des in einem ebenen Feld angeordneten kompakten Elektrodensatzes und der entfernt angeordneten herkömmlichen Elektrode injiziert wird, Äquipotentialflächen in der Nähe des zweidimensionalen Elektrodensatzes kugelförmig ausgebildet sind. Die Vorgehensweise der Rückwärtsprojektion wird auf das Folgende reduziert: für einen gewissen Punkt mit den Koordinaten (X, Y, Z) in dem Objekt unter Betrachtung wird die Entfernung zwischen diesem Punkt und der den Strom injizierenden Elektrode des kompakten Satzes bestimmt. Diese Entfernung entspricht dem Radius r der Äquipotentialfläche, die den Punkt aufweist, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird. Sobald dieser Radius bekannt ist, ist es möglich, die Schnittlinie der Äuipotentialfläche mit der Oberfläche, auf der die Elektroden angeordnet sind, zu bestimmen. Wenn die Elektroden auf der Ebene, welche durch die Gleichung z = 0 wiedergegeben wird, angeordnet sind, ist diese Linie der Kreis, der in der (x,y) Ebene liegt, deren Mittelpunkt an dem Punkt liegt, wo die strominjizierende Elektrode angeordnet ist, und der den Radius r aufweist. Die spezifische elektrische Leitfähigkeit S (in willkürlichen Einheiten) an dem gewählten Punkt wird gemäß folgender Gleichung berechnet:

$$S(x,y,z) = 1 + W_1(z)\sum_i \frac{1}{\int_{L(x,y,z,i)} W_2(l)dl} \int_{L(x,y,z,i)} W_2(l)(E_r(l) - E_m(l))/E_r(l)dl$$

wobei i – die Anzahl der injizierenden Elektrode ist, und L(x,y,z,i) – die Schnittlinie der Äquipotentialfläche mit der Oberfläche, auf der die Elektroden angeordnet sind (Kreis mit dem Radius r) ist. Die Komponenten des elektrischen Feldvektors E_m, werden zuerst an den Knoten des Gitters zwischen den Elektroden als die Potentialdifferenzen zwischen benachbarten Elektroden in die x- und y-Richtungen berechnet. Dann werden diese Komponenten linear zu dem augenblicklichen Integrationspunkt auf der Linie L interpoliert und die Größe des Vektors Ein wird berechnet.

[0023] Die Referenzintensität des elektrischen Feldes E_r entspricht einem homogenen Medium und wird numerisch berechnet. Der Gewichtungskoeffizient $W_1(z)$ korrigiert die mit der Tiefe abnehmende Empfindlichkeit. In der vorliegenden Erfindung wird dazu die empirische Gleichung $W_1 = (z + \alpha)/(z + \beta)$, $\alpha << \beta$ verwendet. Der Gewichtungskoeffizient W_2 liefert einen relativen größeren Beitrag zu der berechneten spezifischen elektrischen Leitfähigkeit dieser Punkte auf der Linie L, die näher an dem Punkt angeordnet sind, an dem die spezi-

fische elektrische Leitfähigkeit rekonstruiert wird. Bei der vorliegenden Vorrichtung wird die Gleichung

$$W_2 = 1/R^2 = 1/((x - x_1)^2 + (Y - Y_1)^2 + z^2)^2$$

verwendet, wobei R die Entfernung zwischen dem Punkt, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird, und dem augenblicklichen Punkt auf der Linie ist, entlang welcher die Integration durchgeführt wird; der Index 1 bezieht sich auf die Koordinaten dieses Punktes.

[0024] Das Verfahren der Rückprojektion ist das schnellste bei der elektrischen Impedanztomographie-Rekonstruktion verwendete Verfahren. Sein Einsatz ist jedoch für die Rekonstruktion der Verteilung der statischen Leitfähigkeit für den 3-D Fall nur dann möglich, wenn die projizierten Werte richtig ausgewählt werden. Darüber hinaus muss die synthetisierte Referenzdatengruppe E_r verwendet werden. Diese wird durch Approximieren der wirklich gemessenen Potentiale gemäß dem Verfahren nach Korjenevsky (A. V. Korjenevsky, Yu. S. Kultiasov, V. A. Cherepenin, "Method of obtaining of tomographic image of a body and electrical impedance tomograph; Verfahren für den Erhalt eines tomographischen Bildes eines Körpers und elektrischer Impedanz-Tomograph in der Patentameldung N 96123647/14 der Russischen Föderation) erhalten.

[0025] In vielen Fällen ist es schwierig, einen ausreichenden Kontakt aller Elektroden mit dem Körper des Patienten zu erzielen. Folglich wird der Schwellenwert-Detektor **8** der Ausgangsspannung verwendet, um zu bestimmen, ob die zu messende Elektrode zu jedem bestimmten Zeitpunkt einen ausreichenden Kontakt mit dem Körper hat. Der kompakte Elektrodensatz ist auf einer steifen dielektrischen Fläche angeordnet und jede Elektrode ist ein leitender Vorsprung von dieser Fläche. Diese Anordnung erlaubt die Untersuchung einer Brustdüse unabhängig deren Größe. Während der Untersuchung wird die Elektrodenfläche gegen die Brust gedrückt, wodurch diese in Richtung des Brustkorbs flach gedrückt wird. Dadurch wird die Anzahl der Elektroden erhöht, die in Kontakt mit dem Körper ist, und die Dicke der zu messenden Gewebeschicht wird verringert. Die vorspringende Eigenschaft der Elektroden verbessert deren elektrischen Kontakt mit dem Körper.

[0026] Eine oder mehrere Elektroden auf dem Umfang der Fläche können keinen Kontakt mit dem Körper aufweisen, abhängig von der Größe des untersuchten Objekts. Diese Elektroden werden mit Hilfe des Schwellenwert-Detektors der Ausgangsspannung, welcher vorstehend erwähnt wurde, erfasst. Die Werte der aus den Elektroden mit unzureichendem Körperkontakt gemessenen Potentialdifferenzen können nicht direkt in dem Verfahren zur Rekonstruktion der Leitfähigkeit verwendet werden. Anstatt dessen werden werte von Potentialdifferenzen verwendet, die unter der Annahme einer homogenen Verteilung der spezifischen elektrischen Leitfähigkeit berechnet wurden.

[0027] Zudem gibt es neben den durch den Stromfluss verursachten nützlichen Potentialdifferenzen noch galvanische Potentialdifferenzen zwischen Elektroden. Das Bauteil zur Messung der Potentialdifferenz **6** spricht nur auf das Wechselstrom-Bauteil an, und wird folglich durch die Anwesenheit dieser konstanten galvanischen Potentialdifferenzen nicht gestört. Aufgrund der Unterschiede bei den galvanischen Potentialen der unterschiedlichen Elektroden variiert die Eingangsspannung jedoch sprunghaft, wenn der Eingabe-Multiplexer **3** geschaltet wird. Diese Sprünge oder plötzlichen Anstiege verursachen eine vorübergehende Spannungsspitze, die die Ergebnisse der Messungen beeinflusst. Dieser Einfluss nimmt zu, wenn das Zeitintervall zwischen dem Einschalten und dem Beginn der Messung der Potentialdifferenz abnimmt. Daher sollte der Eingabe-Multiplexer **3** zur Verringerung des Fehlers, während die Gesamtdauer der Messungen konstant bleibt, die Vorrichtung zur Messung der Potentialdifferenz **6** zur nächsten Elektrode erst dann schalten, nachdem der Ausgabe-Multiplexer **2** den Gesamtzyklus an Umschaltungen der Wechselstromquelle an alle anderen Elektroden beendet hat.

[0028] Fig. 2 zeigt die Anordnung der verschiedenen Bauteile des für die Durchführung von Messungen verwendeten elektrischen Mammographen. Mit Hilfe der Ausgabe-Multiplexer verbindet die Steuereinheit entsprechend den Befehlen vom Computer **11** die Wechselstromquelle mit einer der Elektroden der Kompaktgruppe **1**. Wechselstrom mit einer Stärke von ungefähr 1 mA und einer Frequenz von 10 kHz fließt durch den Schaltkreis, d.h. von der Wechselstromquelle zum Multiplexer, zur Elektrode des Satzes **1**, durch den Körper des Patienten zu der entfernt angeordneten Ruheelektrode **5**. Mit Hilfe des Eingabe-Multiplexers verbindet der Mikroprozessor eine der Ruheelektroden aus der Gruppe **1** mit dem Potentialdifferenz-Detektor. Dieser misst die Amplitude der Wechselspannung zwischen der Elektrode aus der Gruppe **1** und der entfernt angeordneten aktivierten Elektrode **7**. Diese Messung wird in digitalem Code an den Mikroprozessor gesendet, der sie an den Computer **11** weiterleitet.

[0029] Die gemessenen Daten werden zur Rekonstruktion einer 3-D Verteilung der spezifischen elektrischen

Leitfähigkeit mit Hilfe des im Blockdiagramm von Fig. 3 gezeigten Algorithmus verwendet. In Block **12** werden die gemessenen Potentiale der Elektroden aus dem kompakten Satz, welche durch die Verbindungsleitung **10** empfangen werden, für die Synthese der Bezugsgruppe von Potentialen, die einem Körper mit einer homogenen spezifischen elektrischen Leitfähigkeit entsprechen, verwendet. Es wird eine Approximation durch die Methode der kleinsten Quadrate, die in dem Russischen Patent Nr. 96123647/14 beschrieben wird, verwendet. Nur die von Elektroden mit einem guten Körperkontakt erhaltenen Potentiale werden verwendet. In den Blöcken **13** und **14** werden Komponenten des elektrischen Intensitätsvektors für die Referenz-Datengruppe und die gemessene Datengruppe durch Subtraktion der Werte der Potentiale auf benachbarten Elektroden für jede Verbindungsvariante der Stromquelle berechnet. Im letzten Fall werden entsprechende Potentiale aus der Referenzgruppe anstelle der Potentiale derjenigen Elektroden verwendet, die einen unzureichenden Kontakt aufweisen.

[0030] In Block **15** wird der Abstand zwischen der aktivierten Elektrode in der Kompaktgruppe und dem Punkt, an dem die Leitfähigkeit rekonstruiert wird, berechnet. Diese Entfernung bestimmt den Radius eines Kreises, der die Schnittlinie der Äquipotentialfläche mit der Ebene darstellt, auf der die Elektroden angeordnet sind und entlang welcher es nötig ist, eine gewichtete Durchschnittsbildung durchzuführen. Die elektrische Intensität für die gemessene Datengruppe und die Referenz-Datengruppe wird nach der linearen Interpolation der entsprechenden Vektorenkomponenten, die in den Blöcken **13** und **14** berechnet werden, berechnet. Die relative Differenz der elektrischen Intensitäten für die Bezugs- und Messdatengruppe wird mit der Gewichtungsfunktion $1/R^4$ multipliziert, wobei R die Entfernung zwischen dem Punkt, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird, und dem augenblicklichen Punkt auf der Leitung ist, entlang dem eine Durchschnittsbildung durchgeführt wird.

[0031] In Block **16** wird der erhaltene Wert numerisch entlang dem Kreis integriert. Die Vorgänge werden für alle Punkte wiederholt, an denen die Leitfähigkeit rekonstruiert werden soll, und für alle Varianten der aktivierten Elektroden. Dieser Vorgang wird durch Block **17** gesteuert. Das Ergebnis dieser Berechnungen stellt nach der Addition einer Einheit zu erhaltenen Werten eine 3-D Verteilung der spezifischen elektrischen Leitfähgikeit dar, die auf den Durchschnittswert genormt wurde. Das Ergebnis kann auf einem Bildschirm angezeigt oder ausgedruckt werden. Der Block **18** enthält die Software und Hardware, die zur Ausführung dieser Funktionen verwendet wird.

[0032] Das äußere Erscheinungsbild des ekektrischen Mammographen ohne die Recheneinheit ist in Fig. 4 gezeigt. Fig. 5 zeigt einen durch die Erfindung erhaltenen elektrischen Mammographen. Der Mammograph stellt eine Anordnung von 7 Bildern von Brustquerschnitten dar, die parallel zur Fläche liegen, auf der die Elektroden angeordnet sind. Die Tiefe der Querschnitte nimmt von links nach rechts und von oben nach unten in 8mm-Schritten zu. Auf dem Bild sind die Brustwarze **19**, die Rippen **20** und die Grenze **21** zwischen Bereichen mit und ohne ausreichenden Elektrodenkontakt mit dem Körper deutlich zu sehen.

Patentansprüche

1. Verfahren zum Anzeigen eines dreidimensionalen Bildes der Verteilung der spezifischen elektrischen Leitfähigkeit von biologischem Gewebe, wobei das Verfahren die folgenden Schritte aufweist:
Anlegen einer Wechselstrom (AC)-Quelle (**4**) an eine erste aktivierte Elektrode (**1**) eines in einer ebenen Gruppe angeordneten kompakten Elektrodensatzes, wobei der kompakte Elektrodensatz in Kontakt mit der Oberfläche des betreffenden biologischen Gewebes ist, und an eine erste, entfernt positionierte Elektrode (**5**, **7**), welche in Kontakt mit dem Körper, jedoch in einigem Abstand vom kompakten Elektrodensatz positioniert ist;
Messen der Potentialdifferenz zwischen einer ersten Ruheelektrode (**1**) des kompakten Elektrodensatzes und einer zweiten, entfernt positionierten Elektrode (**7**, **5**), wobei die zweite, entfernt positionierte Elektrode in Ruhestellung ist;
Schalten der Wechselstromquelle (**4**) mit Hilfe von Multiplexvorrichtungen (**2**, **3**) zur sukzessiven Aktivierung aller Elektroden (**1**) der ebenen Elektrodengruppe mit Ausnahme der Ruheelektrode von Schritt (b), und Messen wiederum der Potentialdifferenz zwischen den Ruheelektroden in (b) für jede aktivierte Elektrode, um auf diese Weise einen ersten Satz von Potentialdifferenzmessungen für jede aktivierte Elektrode zu erhalten;
Schalten der in dieser ebenen Gruppe zu messenden Elektrode (**1**) mit Hilfe der Multiplexvorrichtungen (**2**, **3**) zu einer zweiten Ruheelektrode (**1**), sukzessives Aktivieren jeder anderen Elektrode in dieser ebenen Gruppe, und Messen wiederum der Potentialdifferenz zwischen der zweiten Ruheelektrode und der entfernt positionierten Ruheelektrode (**7**, **5**), um auf diese Weise einen zweiten Satz von Potentialdifferenzmessungen für jede aktivierte Elektrode zu erhalten;
Fortführen des Schaltens der Ruheelektrode (**1**), des sukzessiven Aktivierens der verbleibenden Elektroden in der ebenen Gruppe, und des Messens wiederum der Potentialdifferenz zwischen der ausgewählten Ruheelek-

trode und der entfernt positionierten Ruheelektrode (**7**, **5**), bis alle planaren Elektrodenkombinationen gemessen worden sind;
Rekonstruieren einer dreidimensionalen Verteilung der spezifischen elektrischen Leitfähigkeit unter Verwendung des Rückwärtsprojektionsverfahrens entlang Äquipotentialflächen des elektrischen Feldes, wobei die projizierten Daten durch gewichtete Durchschnittsbildung der relativen Differenz zwischen der elektrischen Referenzintensität, welche Gewebe mit einer homogenen Verteilung der spezifischen elektrischen Leitfähigkeit entspricht, und der gemessenen elektrischen Intensität entlang der Schnittlinie der Äquipotentialfläche, welche den Punkt aufweist, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird, und mit der Oberfläche, auf der der kompakte Elektrodensatz (**1**) positioniert ist, erhalten wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass eine Schwellenwert-Erfassungsvorrichtung (**8**) bestimmt, ob irgendeine spezifische Elektrode (**1**) der ebenen Gruppe in ausreichendem Kontakt mit dem Gewebe ist, um eine aussagekräftige Messung zu erzielen.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, dass die Werte der Potentialdifferenzen für diejenigen Elektroden (**1**), welche einen unzureichenden Kontakt mit dem Gewebe aufweisen, vielmehr basierend auf der Annahme einer homogenen Verteilung der spezifischen elektrischen Leitfähigkeit berechnet werden, und nicht indem die tatsächlichen gemessenen Potentialdifferenzen herangezogen werden.

4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass der Gewichtungskoeffizient von $1/R^4$ in der gewichteten Durchschnittsbildung von Schritt (f) verwendet wird, wobei R die Entfernung zwischen dem Punkt, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird, und dem augenblicklichen Punkt auf der Linie, entlang welcher die Durchschnittsbildung ausgeführt wird, ist.

5. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass der kompakte Elektrodensatz (**1**) auf einer starren dielektrischen Ebene angeordnet ist, und der leitende Abschnitt einer jeden Elektrode über die Ebene hinausragt.

6. Vorrichtung zur Erzeugung eines dreidimensionalen Bildes der Verteilung der spezifischen elektrischen Leitfähigkeit von biologischem Gewebe, welche Folgendes aufweist:
eine Vielzahl von individuellen Elektroden (**1**), die in einer starren ebenen Gruppe angeordnet sind und in Kontakt mit dem betreffenden biologischen Gewebe angeordnet sind;
eine Wechselstrom (AC)-Quelle (**4**), die an eine der Elektroden (aktive Elektrode) (**1**) in dieser ebenen Gruppe und an eine einzelne, in einigem Abstand von der ebenen Gruppe positionierte entfernt angeordnete und mit dem biologischen Gewebe in Kontakt stehende aktive Elektrode (**5**, **7**) angeschlossen ist;
eine Ausgabe-Multiplexvorrichtung (**2**) zum sukzessiven Schalten der Wechselstromquelle zu anderen Elektroden (**1**) in der ebenen Gruppe, wodurch diese wiederum zu aktiven Elektroden werden;
eine Eingabe-Multiplexvorrichtung (**3**) zum Verbinden einer Potentialdifferenz-Messvorrichtung (**6**) mit einer der nicht aktiven Elektroden (Ruheelektroden) (**1**) in der ebenen Gruppe und mit einer einzelnen, entfernt positionierten Ruheelektrode (**7**, **5**), die in einigem Abstand von der ebenen Gruppe und in Kontakt mit dem biologischen Gewebe angeordnet ist;
an die Eingabe- und Ausgabe-Multiplexvorrichtungen (**2**, **3**) angeschlossene Berechnungsvorrichtungen zum sequentiellen Anlegen der Wechselstromquelle an die Elektroden (**1**) der ebenen Gruppe, während Potentialdifferenzmessungen von anderen Elektroden in der ebenen Gruppe durchgeführt werden, und zum Rekonstruieren einer dreidimensionalen Verteilung der spezifischen elektrischen Leitfähigkeit, indem ein modifiziertes Rückwärtsprojektionsverfahren eingesetzt wird; und
eine Anzeigevorrichtung zum Abbilden der rekonstruierten dreidimensionalen Verteilung der spezifischen elektrischen Leitfähigkeit.

7. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, dass eine Schwellenwert-Erfassungsvorrichtung (**8**) vorgesehen ist, um zu bestimmen, ob eine spezifische Elektrode (**1**) der ebenen Gruppe in ausreichendem Kontakt mit dem Gewebe ist, um eine aussagekräftige Messung zu erzielen.

8. Vorrichtung nach Anspruch 7, dadurch gekennzeichnet, dass bei der Rekonstruktion der Verteilung der spezifischen elektrischen Leitfähigkeit die Werte der Potentialdifferenzen für diejenigen Elektroden (**1**), welche nicht in ausreichendem Kontakt mit dem Gewebe sind, vielmehr basierend auf der Annahme einer homogenen Verteilung der spezifischen elektrischen Leitfähigkeit berechnet werden, und nicht dadurch, dass die tatsächlichen gemessenen Potentialdifferenzen herangezogen werden.

9. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, dass das verwendete modifizierte Rückwärt-

sprojektions-Rekonstruktionsverfahren einen Gewichtungskoeffizienten von $1/R^4$ einschließt, wobei R die Entfernung zwischen dem Punkt, an dem die spezifische elektrische Leitfähigkeit rekonstruiert wird, und dem augenblicklichen Punkt auf der Linie, entlang welcher die Durchschnittsbildung durchgeführt wird, ist.

10. Vorrichtung nach Anspruch 6, dadurch gekennzeichnet, dass die ebene Gruppe von Elektroden (1) auf einer starren dielektrischen Ebene angeordnet ist, und der leitende Abschnitt einer jeden Elektrode über diese Ebene hinausragt.

Es folgen 5 Blatt Zeichnungen

Anhängende Zeichnungen

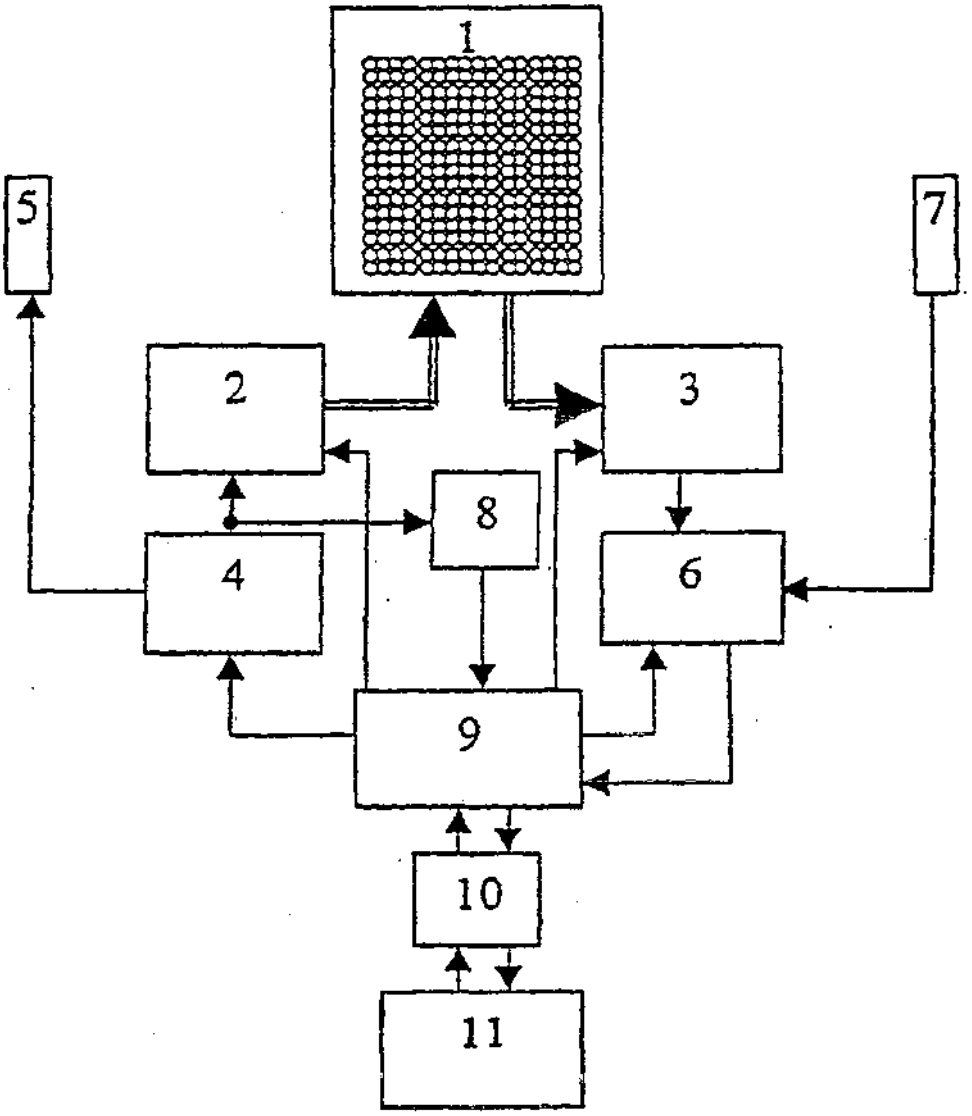


FIG. 1

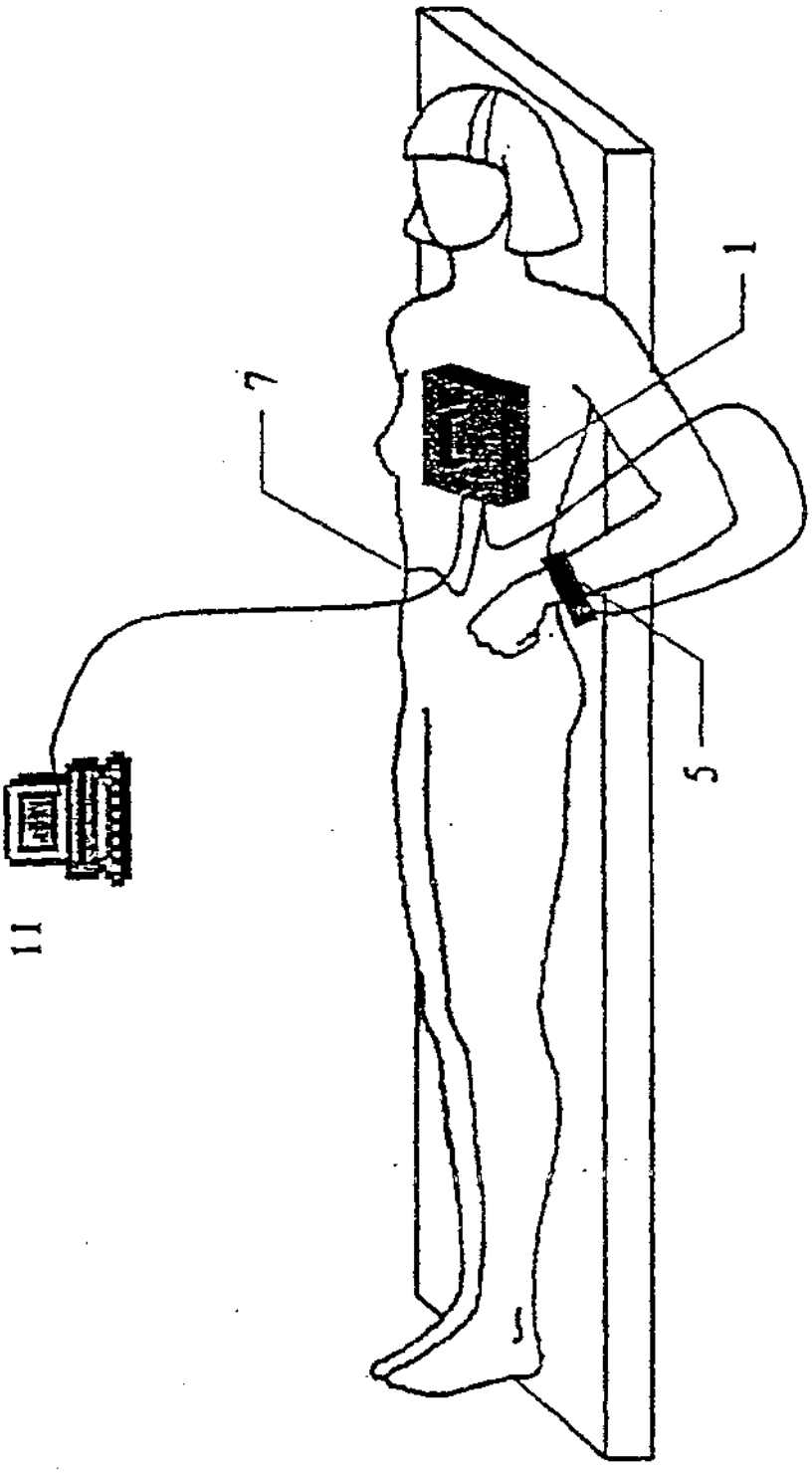


FIG. 2

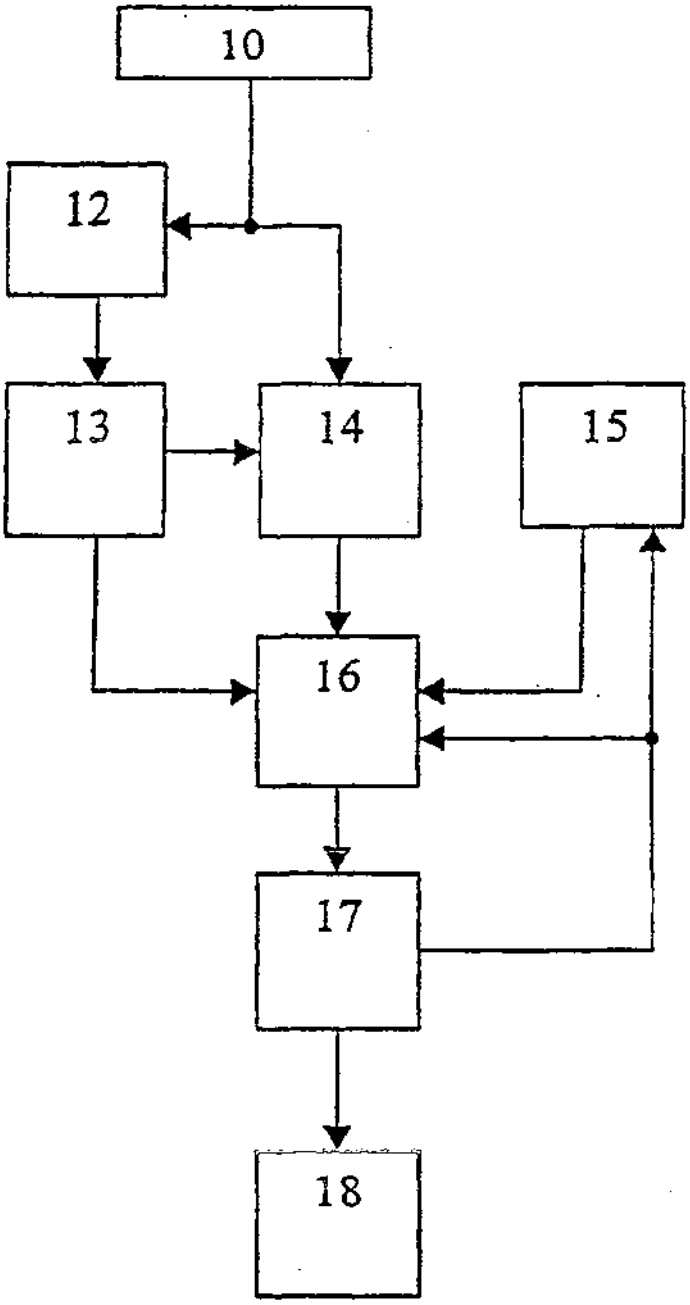


FIG. 3

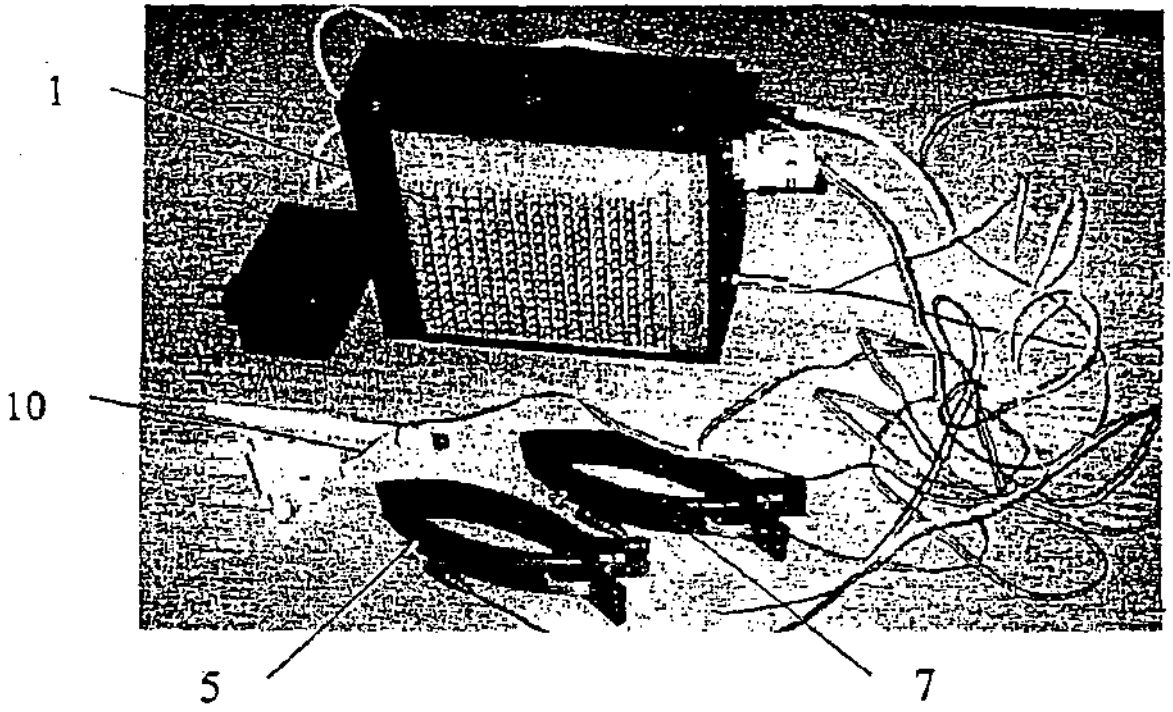


FIG. 4

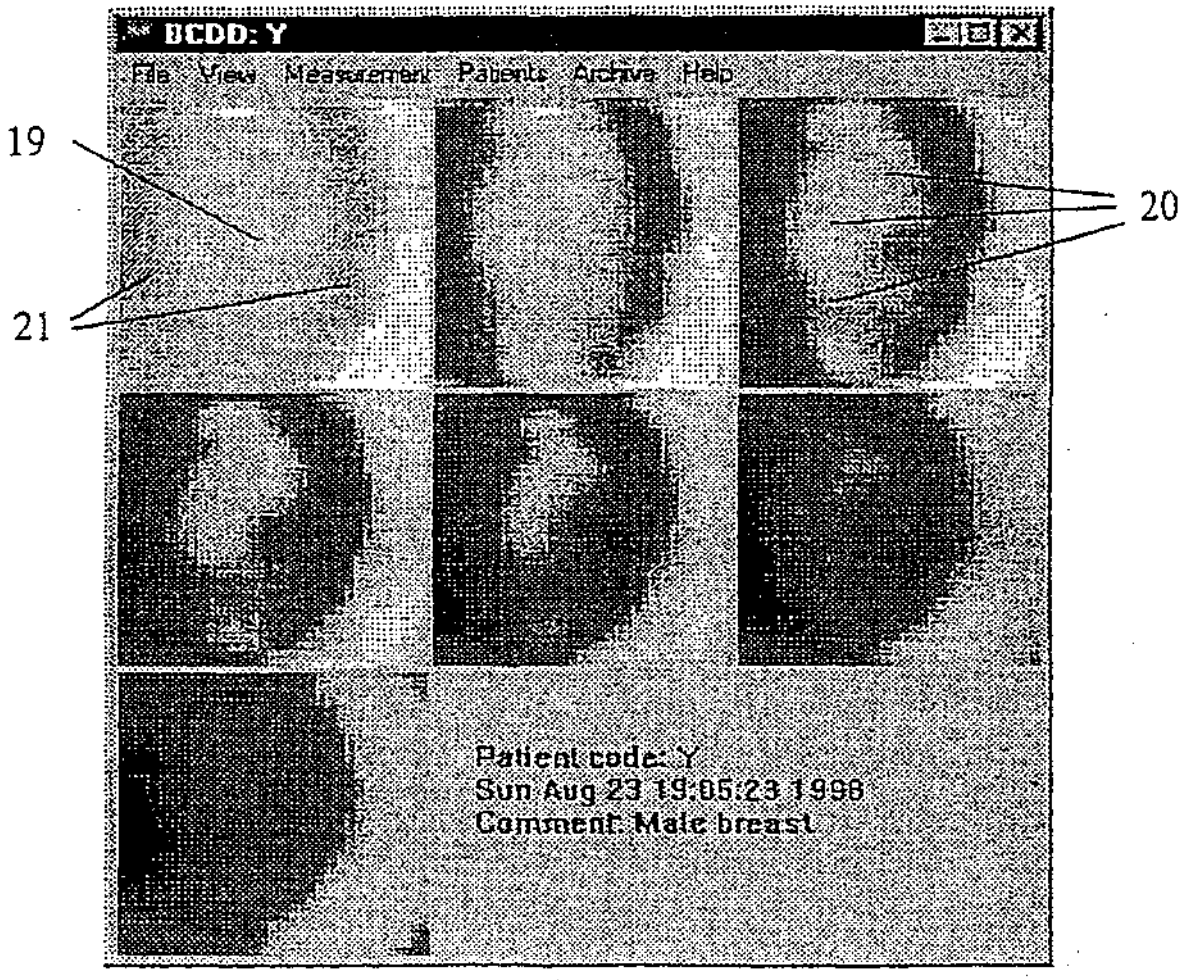

DCDD: Y
File View Measurement Patients Archive Help
19
21
20
Patient code: Y
Sun Aug 23 19:05:23 1998
Comment: Male breast

FIG. 5

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PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2003-317089
(43)Date of publication of application : 07.11.2003

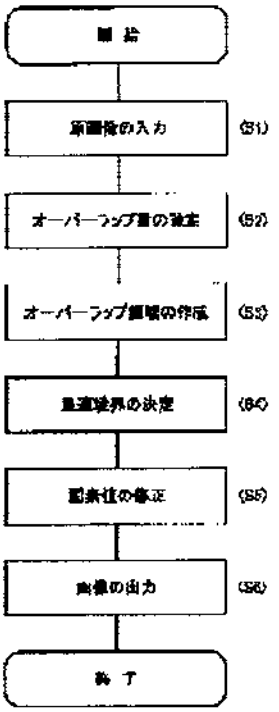
(51)Int.Cl. G06T 3/00
G06T 5/00
H04N 1/387

(21)Application number : 2002-121719
(22)Date of filing : 24.04.2002

(71)Applicant : DAINIPPON PRINTING CO LTD
(72)Inventor : KAWAI NAOKI

(54) METHOD AND SYSTEM FOR IMAGE CORRECTION

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a method and a system for image correction with high processing efficiency and superior reproducibility which can generate an image with an inconspicuous seam when images are joined and eliminate the need for operator's skillfulness and manual operation.
SOLUTION: A source image as an object of endless processing is inputted (S1). After an overlap quantity is set (S2), an overlap area is generated nearby an end of the source image (S3) and in this overlap area, an optimum border as a minimum error border is determined according to pixel values at the end of the source image and other ends (S4). According to the optimum border, the pixel values are corrected (S5) to output a corrected image after the endless processing (S6).



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(19)日本国特許庁（ＪＰ）　(12)公開特許公報（Ａ）　(11)特許出願公開番号
特開2003－317089
（Ｐ2003－317089Ａ）
(43)公開日　平成15年11月7日(2003.11.7)

(51)Int.Cl.'		識別記号	FI			テーマコード'(参考)
G06T	3/00	400	G06T	3/00	400J	5B057
	5/00	100		5/00	100	5C076
H04N	1/387		H04N	1/387		

審査請求 未請求　請求項の数3　ＯＬ　（全７頁）

(21)出願番号　特願2002－121719(P2002－121719)

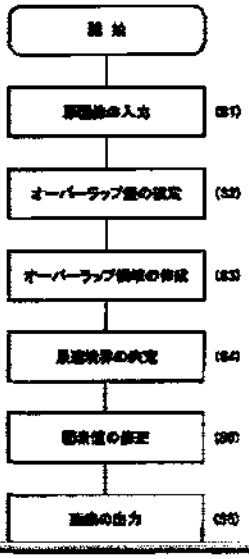
(22)出願日　平成14年4月24日(2002.4.24)

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Ｆターム(参考)　5B057 CA01 CA08 CA12 CA16 CC03
CE10 CE11 CE17 CF03 CH08
DA07 DA08 DA16 DB02 DB06
DB09 DC23 DC25 DC32
5C076 AA12 AA31 BA06 CA01

(54)【発明の名称】　画像修正方法およびシステム

(57)【要約】
【課題】　画像を繋ぎ合わせた際に、その繋ぎ目が目立たない画像を作成することが可能であると共に、作業者の熟練、手作業が不要で処理効率が高く、かつ再現性に優れた画像修正方法およびシステムを提供する。
【解決手段】　エンドレス処理の対象とする原画像を入力する（Ｓ１）。オーバーラップ量を設定した後（Ｓ２）、原画像の端部付近にオーバーラップ領域を作成し（Ｓ３）、このオーバーラップ領域において、原画像の端部と他の端部の画素値に基づいて最小誤差境界となる最適境界を決定する（Ｓ４）。この最適境界に基づいて画素値を修正（Ｓ５）することによりエンドレス処理された修正画像を出力する（Ｓ６）。



http://www4.ipdl.inpit.go.jp/tjswh.ipdl?D=1232393839484
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【特許請求の範囲】
【請求項１】同一の画像の端部と対向する端部を繋ぎ合わせた際に、その繋ぎ目が目立たないように画像を修正する方法であって、
修正対象となる原画像を入力する画像入力段階と、
原画像の繋ぎ目部分におけるオーバーラップ量を設定する段階と、
前記設定されたオーバーラップ量に基づいてオーバーラップ領域を作成する段階と、
前記入力された原画像の端部と対向する端部の境界を、前記オーバーラップ領域における前記端部の画素値と前記対向する端部の画素値の差が最小となる画素の累積に基づいて決定する段階と、
前記決定された境界に基づいて、前記原画像の端部および対向する端部の画素値を修正することにより修正画像を作成する段階と、
を有することを特徴とする画像修正方法。
【請求項２】修正対象となる原画像を入力する原画像入力手段と、
原画像の繋ぎ目部分におけるオーバーラップ量を設定するオーバーラップ量設定手段と、
前記設定されたオーバーラップ量に基づいてオーバーラップ領域を作成するオーバーラップ領域作成手段と、
前記入力された原画像の端部と対向する端部の境界を、前記オーバーラップ領域における前記端部の画素値と前記対向する端部の画素値の差が最小となる画素の累積に基づいて決定する最適境界決定手段と、
前記決定された境界に基づいて、前記原画像の端部および対向する端部の画素値を修正することにより修正画像を作成する画素値修正手段と、
得られた修正画像を出力する画像出力手段と、
を有することを特徴とする画像修正システム。
【請求項３】コンピュータに、
修正対象となる原画像を入力する画像入力段階と、
原画像の繋ぎ目部分におけるオーバーラップ量を設定する段階と、
前記設定されたオーバーラップ量に基づいてオーバーラップ領域を作成する段階と、
前記入力された原画像の端部と対向する端部の境界を、前記オーバーラップ領域における前記端部の画素値と前記対向する端部の画素値の差が最小となる画素の累積に基づいて決定する段階と、
前記決定された境界に基づいて、前記原画像の端部および対向する端部の画素値を修正することにより修正画像を作成する段階と、
を実行させるためのプログラム。
【発明の詳細な説明】

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印刷物に利用される画像の作成に関し、特に繋ぎ目が目立たないようにシームレスなエンドレス画像を作成するための技術に関する。
【０００２】
【従来の技術】建材印刷物は、出版印刷物、商業用印刷物等の汎用印刷物に比べて、長さが非常に長い（長尺）。例えば、壁面に施工する印刷物を考えると、建物の床から天井までの長さは、通常２．５ｍ程度はあり、また部屋の端から端までの水平方向長さも、６畳間の場合で、長辺が３．５ｍ程度はある。したがって、建材印刷物用の画像も、最低限その程度の長さは繋ぎ目なく連続し、一続きとなったエンドレスな画像、すなわちエンドレス画像が必要となる。
【０００３】上記のような長尺の画像を印刷用版胴の１円周以内に収めることは不可能である。そのため、１円周分の画像の印刷方向の始端部の辺と終端部の辺とを版胴上で接続して（繋いで）製版する。そして、印刷時に版胴が１回転することに１円周分の画像が途切れることなく繰返し印刷されることによって、任意の長さの長尺印刷物を得ている。
【０００４】ただし、単に１円周分の画像の印刷方向の始端部の辺と終端部の辺とを突合わせて接続したのみでは、接続部（繋ぎ目）で画像が不連続となり、エンドレス画像は得られない。版胴画像のエンドレス化のためには、画像の繋ぎ目において、繋ぎ目を境界として両側画像の不連続部分を連続化して、繋ぎ目を目視で認識不能とする作業、すなわち、シームレス化が必要となる。
【０００５】そこで、特に木目模様の場合は有効な、画像繋ぎ目のシームレス化による版胴画像のエンドレス化の手法として、特公昭４３－２０６５号公報等記載のごとく、円周上の繋ぎ目を波形、あるいはジグザグの折れ線として、繋ぎ目自体を目立ち難い形状とし、かつ繋ぎ目近傍領域を熱線工が手作業で加筆、脱色、染色、削除等を行うことにより、画像の不連続を修正してシームレス化することが広く行われてきた（従来技術❶）。
【０００６】又近年は、電子計算機を応用したデジタル画像処理技術の進歩によって、原稿画像をスキャナーで読込んでデジタルデータ化し、ＣＲＴ等の表示装置上でマウス、タブレット、カーソル等により修正箇所を指定し、画面内の他の部分等から適当な画像をコピーして移植する等の手法により、より作業性を向上させることが試みられている（従来技術❷）。さらに、繋ぎ目のシームレス化の作業を両側画像の平均化演算処理によって、自動的に所定の式で計算することによって効率化する方法も提案されている（従来技術❸）。
【０００７】
【発明が解決しようとする課題】しかしながら、上記従

JP,2003-317089,A ◉ STANDARD ○ ZOOM-UP ROTATION No Rotation ☐ REVERSAL

http://www4.ipdl.inpit.go.jp/tjswh.ipdl?D=1232393849758
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く同一のシームレス処理の場を再現することも困難である。

【０００８】上記従来技術②においては、シームレス化の作業にデジタル化、機械化した処理を採用することにより、上記従来技術①に比べれば、画像の繋ぎ目等の工程については、作業の効率化は図れた。しかし、特にシームレス化の作業自体は、依然として熟練工の勘と手作業に依存する点においては、ほとんど改善にはなっていない。

【０００９】上記従来技術③では、シームレス化の作業をもデジタル処理により自動化することによって効率化は図られた。しかし、シームレス化が、単に両側の画像を繋ぎ目において加算（平均化）しているため、繋ぎ目近傍において、空間周波数の高周波成分が欠落し、画像の微細構造ないしは先鋭度が低下する。そのため、遠くから見ると依然として繋ぎ目が認識されてしまうという問題点が残ることになる。

【００１０】上記のような点に鑑み、本発明は、その精度が高く繋ぎ目が目立たない画像を作成することが可能であると共に、作業者の熟練、手作業が不要で処理効率が高く、かつ再現性に優れた画像修正方法およびシステムを提供することを課題とする。

【００１１】

【課題を解決するための手段】上記課題を解決するため、本発明では、同一の画像の端部と対向する端部を繋ぎ合わせた際に、その繋ぎ目が目立たないように画像を修正する方法として、修正対象となる原画像を入力する画像入力段階、原画像の繋ぎ目部分におけるオーバーラップ量を設定する段階、前記設定されたオーバーラップ量に基づいてオーバーラップ領域を作成する段階、前記入力された原画像の端部と対向する端部の境界を、前記オーバーラップ領域における前記端部の画素値と前記対向する端部の画素値の差が最小となる画素の累積に基づいて決定する段階、前記決定された境界に基づいて、前記原画像の端部および対向する端部の画素値を修正することにより修正画像を作成する段階を実行するようにしたことを特徴とする。

【００１２】本発明によれば、原画像の繋ぎ目部分におけるオーバーラップ量に基づいて作成されるオーバーラップ領域において、原画像の端部と対向する端部の境界をその画素値の差が最小となる画素の累積に基づいて決定するようにしたので、画像を複数配列した際にも、繋ぎ目が目立たない画像を作成することが可能となる。

【００１３】

【発明の実施の形態】以下、図面を参照して本発明の一実施形態について詳細に説明する。

（1.システム構成）まず、本発明に係る画像修正システ

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量設定手段、３は演算制御装置、３ａはオーバーラップ領域作成手段、３ｂは最適境界決定手段、３ｃは画素値修正手段、４は画像出力手段である。

【００１４】原画像入力手段１は、シームレス処理、エンドレス処理の対象となる原画像を入力するためのものであり、デジタルデータの読取装置で原画像データを読取らせることにより実現される。また、原画像が紙媒体等に描画されている場合は、スキャナ、デジタルカメラ等を利用してデジタル化した後入力する。オーバーラップ量設定手段２は、原画像の端部と対向する端部をどの程度オーバーラップ、すなわち重複させるかを設定するためのものであり、マウス、キーボード等の入力機器で実現される。

【００１５】演算制御装置３は、本発明の中心的な役割を有するものであり、入力された原画像、設定されたオーバーラップ量に基づいて、原画像の両端部を修正することによりエンドレス化された修正画像を作成する機能を有している。実際には、コンピュータのＣＰＵ、メモリで構成され、メモリに専用のプログラムを読込み、ＣＰＵが順次実行することにより実現される。演算制御装置３は、さらにオーバーラップ領域作成手段３ａ、最適境界決定手段３ｂ、画素値修正手段３ｃを有している。オーバーラップ領域作成手段３ａは、入力された原画像のサイズおよび設定されたオーバーラップ量に基づいて、オーバーラップ領域のサイズを計算し、算出された大きさのメモリ空間を確保する機能を有している。最適境界決定手段３ｂは、オーバーラップ領域内の原画像の端部の画素値と対向する他の端部の画素値に基づいて原画像の端部と対向する他の端部の最適な境界を決定する機能を有している。画素値修正手段３ｃは、決定された最適境界に基づいて原画像上の画素値を変更する機能を有している。オーバーラップ領域作成手段３ａ、最適境界決定手段３ｂ、画素値修正手段３ｃはそれぞれ専用のプログラムをＣＰＵで実行することにより実現される。画像出力手段４は、作成された修正画像を出力する機能を有しており、画像を表示するためのディスプレイ装置、印刷するためのプリンター、データとして出力するためのハードディスク等の外部記憶装置、携帯可能な電子記録媒体への記録装置、さらにネットワークを介して遠隔地へ送信するための通信装置等が適用可能である。

【００１６】（2.処理の流れ）次に、本発明に係る画像修正方法について、図１に示した画像修正システムの処理動作と共に説明する。図２は本発明に係る画像修正方法の概要を示すフローチャートである。まず、原画像入力手段１より、エンドレス処理を行う対象となる原画像を入力する（ステップＳ１）。次に、オーバーラップ量設定手段２を用いて、オーバーラップ量の設定を行う

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域が決定される。オーバーラップ領域とは、原画像の端部と対向する端部の境界付近において、最適な境界を決定するための領域である。この最適境界決定処理を行わないと、原画像を複数並べた際に、互いの境界部で段差が目立つことになる。本実施形態では、オーバーラップ量の設定は、１方向で原画像の端部と対向する端部が互いに重なり合う画素数で設定される。

【００１７】続いて、入力された原画像のサイズ、および設定されたオーバーラップ量に基づいてオーバーラップ領域の作成を行う（ステップＳ３）。具体的には、オーバーラップ領域作成手段３ａが、コンピュータの主記憶装置内にオーバーラップ領域として必要なメモリ空間の確保を行う。例えば、原画像G_{ori}のサイズ（画素数）が横ｘｐ×縦ｙｐであったとする。このとき、図３（ｂ）に示すように原画像G_{ori}をｘ軸方向（図中左右方向）に複数並べた際に、隣接する原画像G_{ori}と接する辺の長さ（画素数）はｙｐであるので、オーバーラップ量がαであるとすると、ｙｐ×αの大きさのオーバーラップ領域Ｏが作成される。本発明で処理する原画像G_{ori}は１つだけであり、図３（ｂ）に示したように複数並べた場合の左右の画像は同じ原画像G_{ori}であるが、ここでは説明の便宜上、一方を原画像G_L、他方を原画像G_Rとする。図３（ｂ）に示すように原画像G_Lと原画像G_Rにまたがってｙｐ×αの大きさのオーバーラップ領域が作成されることになる。

【００１８】オーバーラップ領域が作成されたら、次に、このオーバーラップ領域における原画像G_Lと原画像G_Rの最適な境界を決定する（ステップＳ４）。具体的には、オーバーラップ領域において、原画像G_Lと原画像G_Rの画素値の差の累計が最小となる最小誤差境界を求め、元の原画像の左辺、原画像の右辺の代わりに、求めた最小誤差境界を原画像G_Lと原画像G_Rの境界とする処理を行う。求められた最小誤差境界が最適境界となる。

【００１９】このような最小誤差境界の決定の手法としては、種々のものが提案されているため、FloydやDijkstraのアルゴリズム等の周知のものを適用すれば良いが、本実施形態における手法を具体的に説明する。図４にオーバーラップ量α＝６とした場合の原画像G_Lと原画像G_Rのオーバーラップ領域Ｏ付近を示す。図４の例では、α＝６であるため、オーバーラップ領域にはｘ軸方向（図の左右方向）に６画素分用意されることになる。このようなオーバーラップ領域の場合、まず、第１行目の６個の画素について、原画像G_Lの画素値と原画像G_Rの画素値との比較を行う。この両者の差を最小とする位置の算出には、一般にL^2距離として知られる値を用いる。例えば、ある画素Ｑにおいて、原画像G_Lの

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【００２０】〔数式１〕

$$L^2 = (Q_L - Q_R)^2$$

【００２１】オーバーラップ領域全域に渡って、この値を計算すると、この配列はちょうどそこを境界とした誤差のマップになる。したがって、この（６×ｙｐ）画素の領域で上端（第１行目）から下端（第ｙｐ行目）に至る全ての経路について、途中の各要素のL^2を累積していき、この累積したコスト（値）が最も小さな経路を、最も好ましい境界とするのである。なお、対象としている画像がカラーの場合は、各色に対応したチャンネルのL^2の値の総和をとるものとする。このようにして、累積したコスト（値）が最も小さな経路を決定していくことにより、最小誤差境界が得られる。

【００２２】最適境界が決定されたら、決定された最適境界に基づいて、画素値修正手段３ｃが、原画像の画素値の修正を行う（ステップＳ５）。例えば、オーバーラップ領域において、図５に示すような最小誤差境界が得られた場合を考えてみる。図５において、網掛けで示す画素が最小誤差境界である。この場合、最小誤差境界よりも左側にある画素は、原画像G_Lの画素値を採用し、最小誤差境界よりも右側にある画素は、原画像G_Rの画素値を採用する。また、本実施形態では、最小誤差境界上に存在する画素については、原画像G_Lと原画像G_Rの画素値の平均を採るものとしている。図５において、「Ｌ」で示された画素は原画像G_Lの画素値が、「Ｒ」で示された画素は原画像G_Rの画素値がそれぞれ与えられることを示している。原画像の画素値を修正することにより修正画像が得られたら、画像出力手段４より出力する（ステップＳ６）。

【００２３】ここで、最小誤差境界の求め方の概要を整理しておく。最小誤差境界の求め方の概要を図６のフローチャートに示す。最小誤差境界を求めるためには、まず、第１行目の全画素（図の例では６画素）について各画素におけるL^2値を累積コストとして記憶する（ステップＳ１１）。続いて、第２行目の各画素について、自身の左上、真上、右上の画素について、最小の累積コストを持つものを、この画素に至る最短経路として記憶すると共に、その上側の画素の累積コストに自身のL^2値を加算したものを、自身の累積コストとして記憶する（ステップＳ１２）。このステップＳ１２の処理を最終行、図４、図５の例では第ｙｐ行目まで繰り返す。最終行の全画素のうち、最小の累積コストを持つ画素とそこに至る経路を最小誤差境界とする（ステップＳ１３）。

【００２４】この結果、図３（ｂ）に示したオーバーラップ領域Ｏには、図７（ａ）に示すような最適境界Ｂが得られることになる。図７（ａ）において、最適境界Ｂの右側は原画像G_Rの画素値、最適境界Ｂの左側は原画

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区切られた画像を並べるイメージとなる。しかし、図7（b）に示すように画像の形状が、最適境界で示したような曲線であるのは現実的ではない。実際には、原画像の片側（例えば右側）のオーバーラップ領域を削除し、その領域の最適境界より右側の画素値を、対応する左側のオーバーラップ領域にコピーする。具体的には、図7（c）に示すように、原画像G_{org1}のP_aで示した領域の画素に、P_a'で示した領域の画素がコピーされ、原画像G_{org1}のP_bで示した領域およびP_b'で示した領域が削除されることになる。すなわち、上記説明においては、説明の便宜上、図3（b）に示したように2つの画像を並べた状態で説明したが、実際には、1つの原画像の両端部（図3（a）および図7（c）の例では左右の両端部）の画素値に対して修正と削除が行われる。このようにして得られた修正画像をx軸方向に複数並べていくことにより、繋ぎ目が目立たなくなる。

【0025】上記の例では、原画像をx軸方向に複数配列する場合にエンドレス画像となるように画像の修正を行ったが、y軸方向に複数配列する場合であってもx軸とy軸が入れ替わるだけであり、本質的には同様の処理が行われる。また、x軸方向、y軸方向の双方に画像を配列する場合には、x軸方向、y軸方向の双方に上記画像修正処理を行うことにより、縦横の2次元に画像を配列した場合でも全ての繋ぎ目が目立たないような修正画像を得ることが可能となる。

【0026】また、上記の例では、同一の画像を複数並べる場合について説明したが、接続する辺の長さ（画素数）が等しい複数の画像を順に繋ぎ目を目立たないように接続し、左端の画像の左端部と右端の画像の右端部を同様にオーバーラップ領域で最適境界で接続することで、シームレスな画像を作成することもできる。例えば、図3（b）、図7（a）の原画像G_R、原画像G_Lとして別の画像を利用して修正処理を行うことになる。

【0027】

【発明の効果】以上、説明したように本発明によれば、エンドレス画像となるように修正すべき原画像を入力し、隣接する原画像とのオーバーラップ量を設定し、設定されたオーバーラップ量に基づいてオーバーラップ領域を作成し、入力された原画像の端部と対向する端部の境界を、オーバーラップ領域における前記端部の画素値と対向する端部の画素値の差が最小となる画素の累積に基づいて決定し、決定された境界に基づいて、原画像の端部の画素値を修正することによりエンドレス画像を作成するようにしたので、複数配列した際にも、繋ぎ目が目立たない画像を作成することが可能となるという効果を奏する。

【図面の簡単な説明】

【図1】本発明に係る画像修正システムの構成図である。

【図2】本発明に係る画像修正方法のフローチャートである。

【図3】原画像G_{org1}、および原画像G_{org2}を複数並べる場合のオーバーラップ領域Oの関係を示す図である。

【図4】オーバーラップ領域O付近を示す図である。

【図5】最適境界決定後のオーバーラップ領域O付近を示す図である。

【図6】最小誤差境界の求め方の概要を示すフローチャートである。

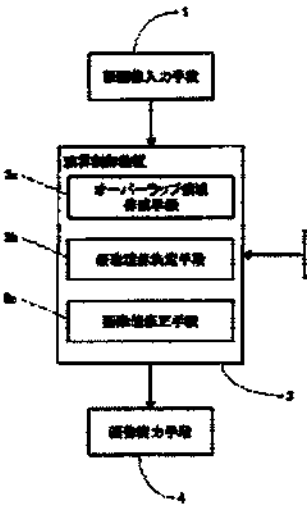
【図7】最適境界決定により得られる修正画像の状態を示す図である。

【符号の説明】

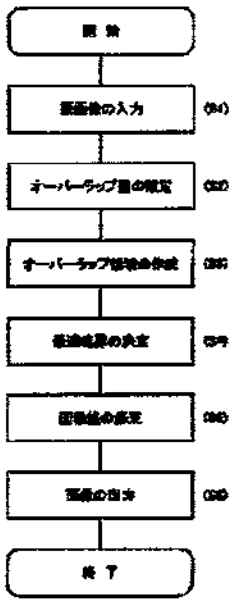
1・・・原画像入力手段
2・・・オーバーラップ量設定手段
3・・・演算制御装置
3a・・・オーバーラップ領域作成手段
3b・・・最適境界決定手段
3c・・・画素値修正手段
4・・・画像出力手段

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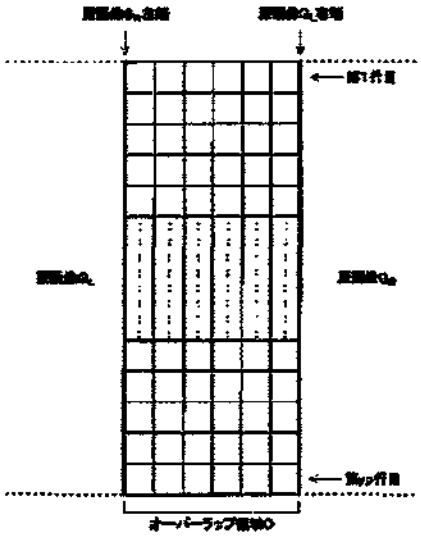
【図１】



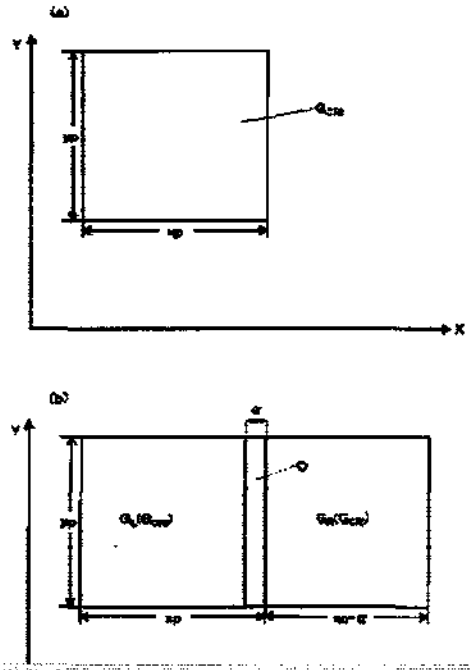
【図２】



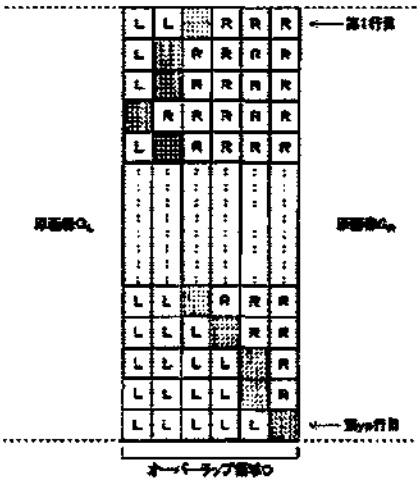
【図４】



【図３】

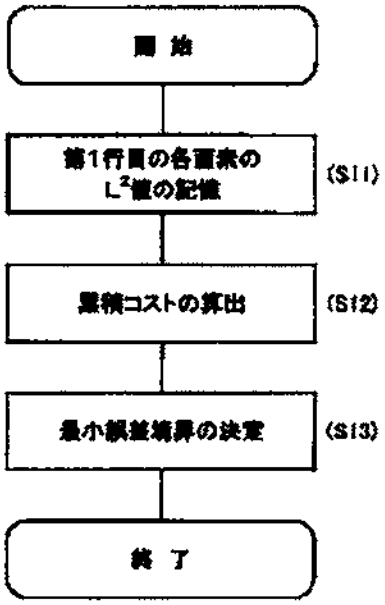


【図５】

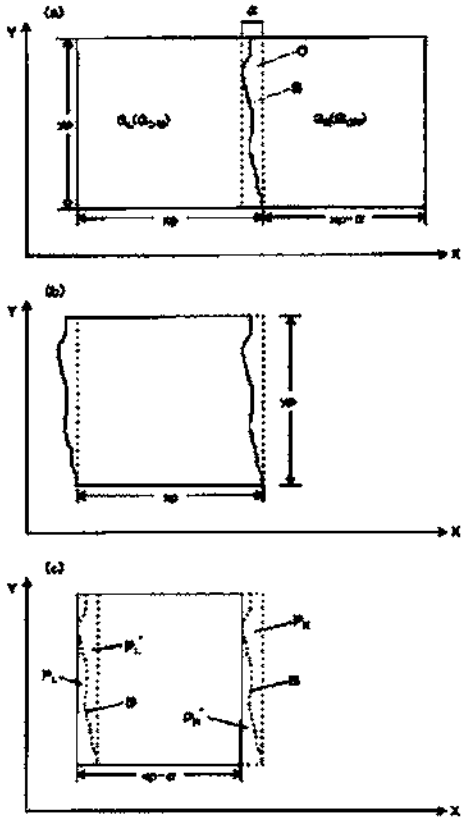


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【図6】



【図7】



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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 May 2004 (27.05.2004)

PCT

(10) International Publication Number
WO 2004/044692 A2

(51) International Patent Classification[7]: G06F

(21) International Application Number:
PCT/US2003/035528

(22) International Filing Date:
7 November 2003 (07.11.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/425,275 8 November 2002 (08.11.2002) US

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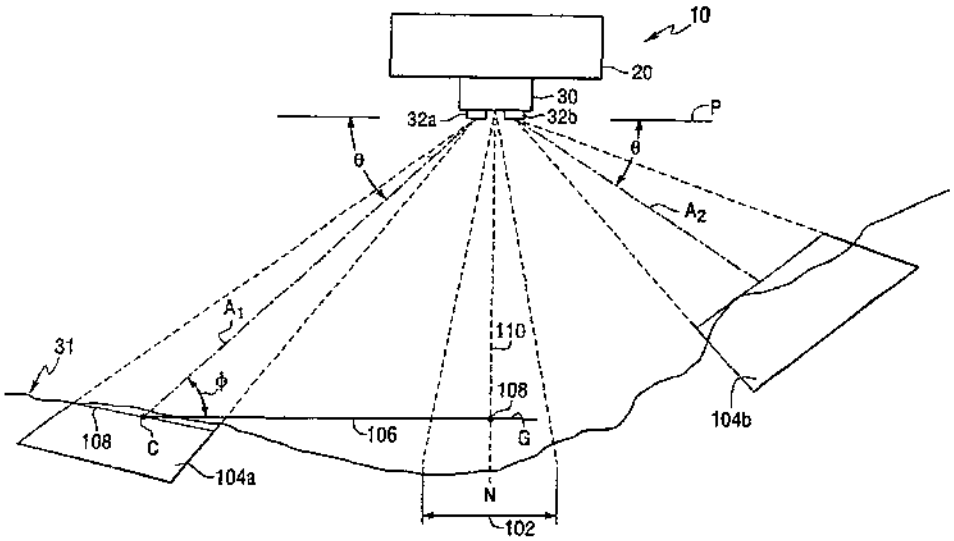
(81) Designated States *(national)*: AE, AG, AL, AM, AU, AZ, BA, BB, BR, BY, BZ, CA, CN, CO, CR, CU, DK, DM, DZ, EC, EE, ES, FI, GD, GE, GH, GM, HR, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, RU, SC, SD, SG, SL, SY, TJ, TM, TN, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM



(57) **Abstract:** A computerized system for displaying, geolocating, and taking measurements from captured oblique images includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

WO 2004/044692 A2

OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is

orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or

inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectfified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the

surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which measurements can be made and reducing the accuracy of any such measurements.

Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein.

Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique

images.

Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for capturing, displaying, and making measurements of objects and distances between objects depicted within oblique images.

The present invention comprises, in one form thereof, a computerized system for displaying, geolocating, and taking measurements from captured oblique images. The system includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area

encompassed within, relative elevation of, and height difference between selected points.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby;

FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1;

FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2;

FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1;

FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1;

FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement

of and between objects depicted in such an image;

FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention;

FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-

capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as will be more particularly described hereinafter.

As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A_1 and A_2, and are mounted to platform 20 such that axes A_1 and A_2 are each at an angle of declination ? relative to a horizontal plane *P*. Declination angle ? is virtually any oblique angle, but is preferably from approximately 20° (twenty degrees) to

approximately 60° (sixty degrees) and is most preferably from approximately 40° (forty degrees) to approximately 50° (fifty degrees).

GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and

stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by mage-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer, includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in

memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals

64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

Image and data acquiring software 90 decodes as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the

amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point *N* of orthogonal image 102. Thus, the exact geo-location of the nadir point *N* of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir

point *N* of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination ? of the primary axes A_1 *and* A_2 of image-capturing devices 32a and 32b, respectively.

It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I_1, I_2, . . . , I_n corresponding to captured oblique images, and the positional data C_{PD1}, C_{PD2}, . . .

, C_{PDn} corresponding thereto.

Image files I_1, I_2, . . . , I_n of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} which is also stored as computer-readable data. Alternatively, positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} is embedded within the corresponding image files I_1, I_2, . . . , I_n in known manner. Image data files 120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and

interaction of a user with image display and analysis software 140 being executed by image display and measurement computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images I_1, I_2, . . . , I_n of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or fitted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the

geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars *M*, or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel

154.

When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142

corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 154 which, for simplicity, corresponds to center *C* (Fig. 1) of oblique image 104a. As shown in Fig. 1, line 106 extends along horizontal plane *G* from a point 108 thereon that is directly below image-capturing device 32a to the center *C* of the near border or edge 108 of oblique image 104a. An extension of primary axis A_1 intersects with center *C*. Angle Ø is the angle formed between line 106 the extension of primary axis A_1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center *C*, and having sides 106, the extension of primary axis A_1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

Ground plane *G* is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle Ø and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A_1) and remaining other side of the right triangle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center *C* of oblique image 104a to be determined by image display

and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path *P1* or a path *P2* that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected

therewith.

It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths *P1* and *P2*, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths *P1* and *P2* also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A_1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

For example, if surface 31 slopes upward between nadir point *N* and center *C* at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center *C* is fifteen feet higher than nadir point *N* and with a declination angle ? equal to 40° (forty degrees), the calculated location of center *C* would be off by approximately 17.8 feet without correction for the change in elevation between the points.

As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant inaccuracies in the measurement of and

between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, survey data, and various other sources.

Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc, within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an

area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed above, and that elevation is used within the location calculation.

Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally

uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest – how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an

angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180° (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are

perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a

community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially constant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction

captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary. In fact,

In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180° (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other.

While the present invention has been described as having a preferred design, the invention can be further modified within the spirit and scope of this disclosure. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A system for capturing images and geo-location data corresponding thereto, comprising:

an image-capturing device, said image-capturing device capturing oblique images at image-capturing events, said image capturing device issuing image-data signals corresponding to captured images;

at least one geo-locating device, each said at least one geo-locating device issuing a corresponding at least one geo-locating signal, each said at least one geo-locating signal being indicative at least in part of a geo-location of said image-capturing device during each image capturing event; and

a computer system receiving and storing said image-data signals and said at least one geo-locating signal; and

image and data acquiring software reading said image-data signals and said at least one geo-locating signal, said software associating each said image-data signal with a corresponding said at least one geo-locating signal for each image-capturing event.

2. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise at least one of:

a clock issuing to said image-capturing computer system time data signals

indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

3. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise:

a clock issuing to said image-capturing computer system time data signals indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

4. The system of claim 1, further comprising correction data indicative of characteristics of said image-capturing device including focal length, sensor size, radial distortion, principal point offset and alignment, said image and data acquiring software utilizing said correction data to correct captured images.

5. The system of claim 1, further comprising an output data file created by said image and data acquiring software, said output data file including a plurality of image files and positional data corresponding to each of said plurality of image files.

6. The system of claim 1, further comprising a platform carrying said image-capturing device a predetermined distance above a surface of interest.

7. A computerized system for displaying, geolocating, and making measurements based upon captured oblique images, comprising:

a computer system having a memory;

an image and data file accessible by said system and including a plurality of image files corresponding to a plurality of captured oblique images, said image and data file further including positional data corresponding to said plurality of image files;

image display and analysis software executed by said system for reading said image and data file and displaying at least a portion of the captured oblique images as a displayed image, said software retrieving said positional data of one or more selected points within said displayed image, said software calculating a separation distance between any two or more selected points within said displayed image.

8. The system of claim 7, further comprising a ground plane data file representing a tessellated ground plane, said ground plane data file accessible by said

computer system, said ground plane data file representing a tessellated ground plane that closely approximates at least a portion of the terrain depicted within said captured oblique images.

9. The system of claim 8, wherein said tessellated ground plane further comprises a plurality of interconnected facets, each of said plurality of facets having a respective pitch and slope.

10. The system of claim 9, wherein said ground plane data file comprises a plurality of vertices, each of said plurality of vertices having respective elevations and defining corners of said plurality of interconnected facets, two of said plurality of vertices shared by each of said interconnected facets.

11. The system of claim 10, wherein said image display and analysis software identifies which of said plurality of facets corresponds to a selected point on said displayed image, and calculates an elevation of said selected point dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point, said image display and analysis software using said calculated elevation for calculating said separation distance between said selected point and one or more further selected points.

12. The system of claim 11, wherein said image display and analysis software calculates a height of an object within said displayed image by calculating the separation distance between two or more selected points.

13. The system of claim 8, wherein said tessellated ground plane is one of superimposed upon and fit to said displayed image.

14. The system of claim 7, wherein said image display and analysis software includes user-selectable measuring modes accessible through at least one of pull-down menus, toolbars and keyboard commands.

15. The system of claim 7, wherein each of said images were captured by an image-capturing device and at respective image capturing events, said positional data of said image and data file including:

time data representing the time of each image-capturing event;

location data representing the location of the image-capturing device at each image-capturing event;

orientation data representing the orientation of the image-capturing device at each image-capturing event;

correction data representing correction factors for the image-capturing device; and

elevation data representing an average elevation of the surface captured by the image-capturing device.

16. The system of claim 15, wherein said location data includes latitude, longitude, and altitude of the image-capturing apparatus at each image-capturing event.

17. The system of claim 15, wherein said orientation data includes roll, pitch, yaw and heading of said image-capturing device at each image-capturing event.

18. The data set of claim 15, wherein said image-capturing device is a camera and said correction data includes at least one of focal length, sensor size, aspect ratio, principle point offset, distortion, and pixel pitch.

19. A computerized method for taking measurements within a displayed oblique image, comprising:

selecting with an input device a starting point and an end point on the displayed image;

retrieving from a data file positional data corresponding to said starting point and said end point;

referencing a ground plane data file corresponding to a tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said

tessellated ground plane closely matching a terrain of said displayed oblique image;

connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

20. The method of claim 19, wherein said tessellated ground plane is superimposed upon said displayed oblique image.

21. The method of claim 19, comprising the further steps of:

selecting with an input device one or more intermediate points on the displayed image;

retrieving from said data file positional data corresponding to said one or more intermediate points; and

connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the distance along said line segments between said starting and end points.

22. The method of claim 19, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

23. The method of claim 19, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

24. A computerized method for taking measurements from an oblique image displayed on a computer system, at least one input device connected to said computer system, an image data file accessible by said computer system, said image data file including captured images and positional data corresponding thereto, said computerized method comprising:

placing the computer system into a desired one of a plurality of measurement modes, the desired measurement mode configured for calculating a desired measurement;

selecting a starting point on the displayed image;

retrieving the positional data corresponding to said starting point;

selecting an end point on the displayed image;

retrieving the positional data corresponding to said end point; and

calculating the desired measurement dependent at least in part upon said positional data of said starting and end points.

25. The method of claim 24, comprising the further steps of:

selecting one or more intermediate points on said displayed image; and

retrieving the positional data corresponding to said intermediate points.

26. The method of claim 24, wherein said plurality of measurement modes comprise a distance measuring mode calculating a distance between two or more selected points, a height measuring mode calculating a height difference between two or more selected points, a relative elevation measurement mode calculating the difference in elevation of two or more selected points, and an area measurement mode calculating the area encompassed by at least three points.

27. A method of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said method comprising:

subdividing the area of interest into a plurality of sectors;

guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective;

guiding the platform along a second path to thereby target said target sectors;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective;

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and

recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

28. The method of claim 27, wherein said second path is substantially parallel relative to and 180° (one-hundred and eighty degrees) from said first path;

29. The method of claim 28, wherein said second path is also spaced apart from said first path.

30. The method of claim 27, comprising the further steps of:

guiding the platform along a third path to thereby target one or more target sectors with the image-capturing device, said third path being substantially perpendicular to said first and second paths;

capturing with the image-capturing device one or more oblique images to thereby

capture an entirety of each said target sector in oblique images captured from a third perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

31. The method of claim 30, comprising the further steps of:

guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180° (one-hundred and eighty degrees) from said third path;

capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

32. The method of claim 31, wherein said fourth path is also spaced apart from said third path.

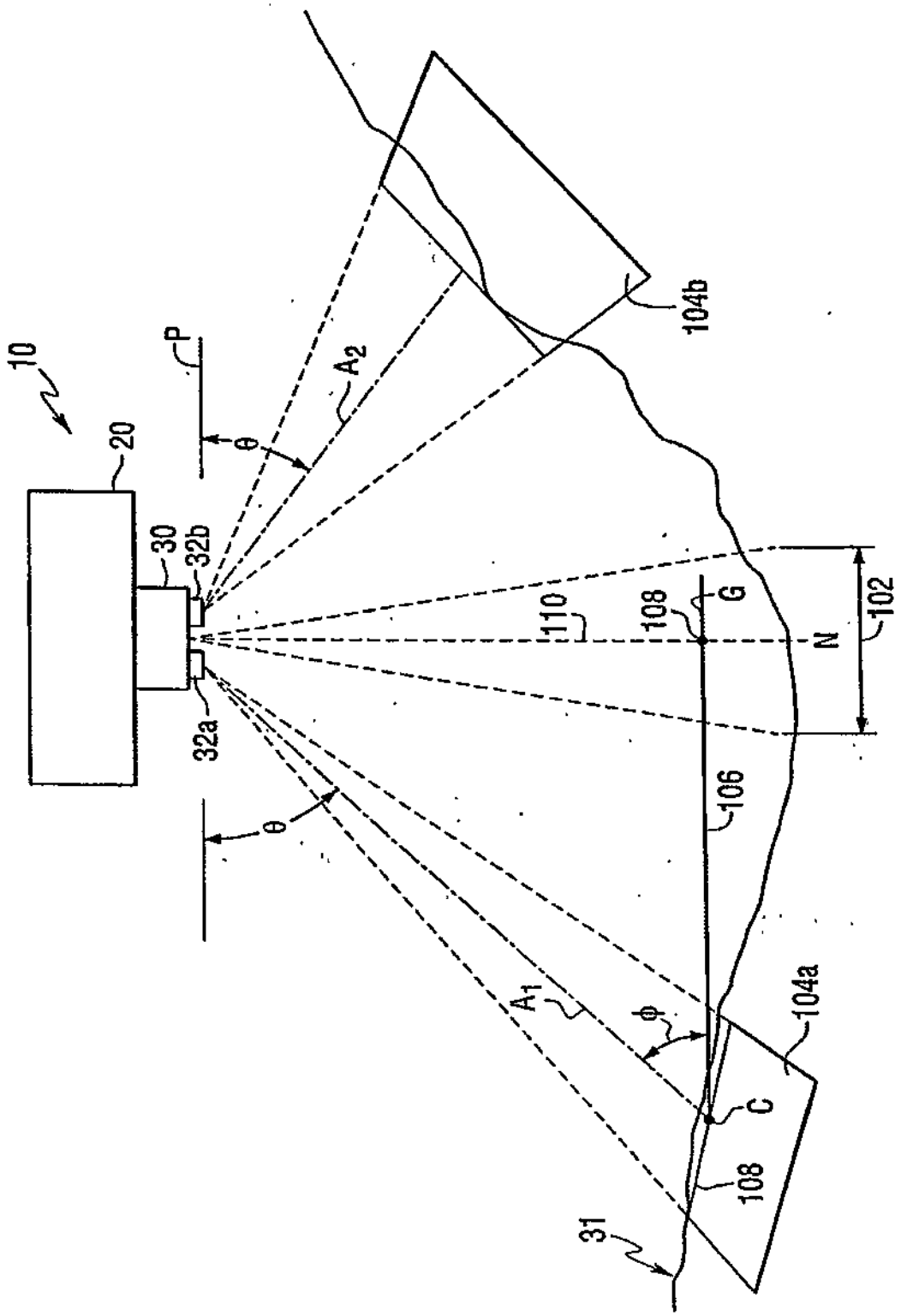


FIG. 1

2/7

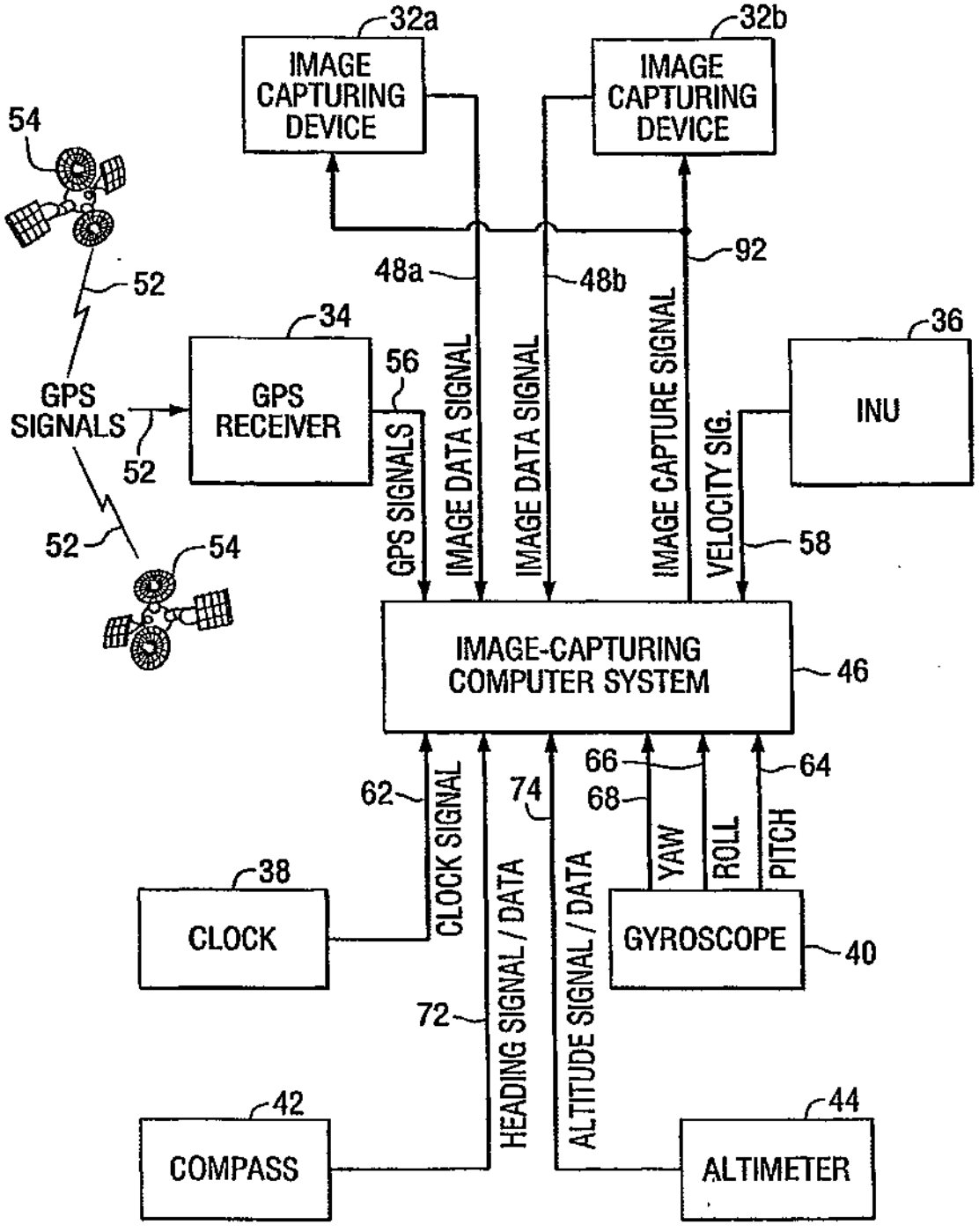

32a
IMAGE CAPTURING DEVICE
32b
IMAGE CAPTURING DEVICE
54
52
GPS SIGNALS
52
34
GPS RECEIVER
56
GPS SIGNALS
48a
IMAGE DATA SIGNAL
48b
IMAGE DATA SIGNAL
92
IMAGE CAPTURE SIGNAL
36
INU
VELOCITY SIG.
58
52
54
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
CLOCK SIGNAL
74
HEADING SIGNAL / DATA
ALTITUDE SIGNAL / DATA
66
68
YAW
ROLL
PITCH
64
38
CLOCK
GYROSCOPE
40
72
42
COMPASS
44
ALTIMETER

FIG. 2

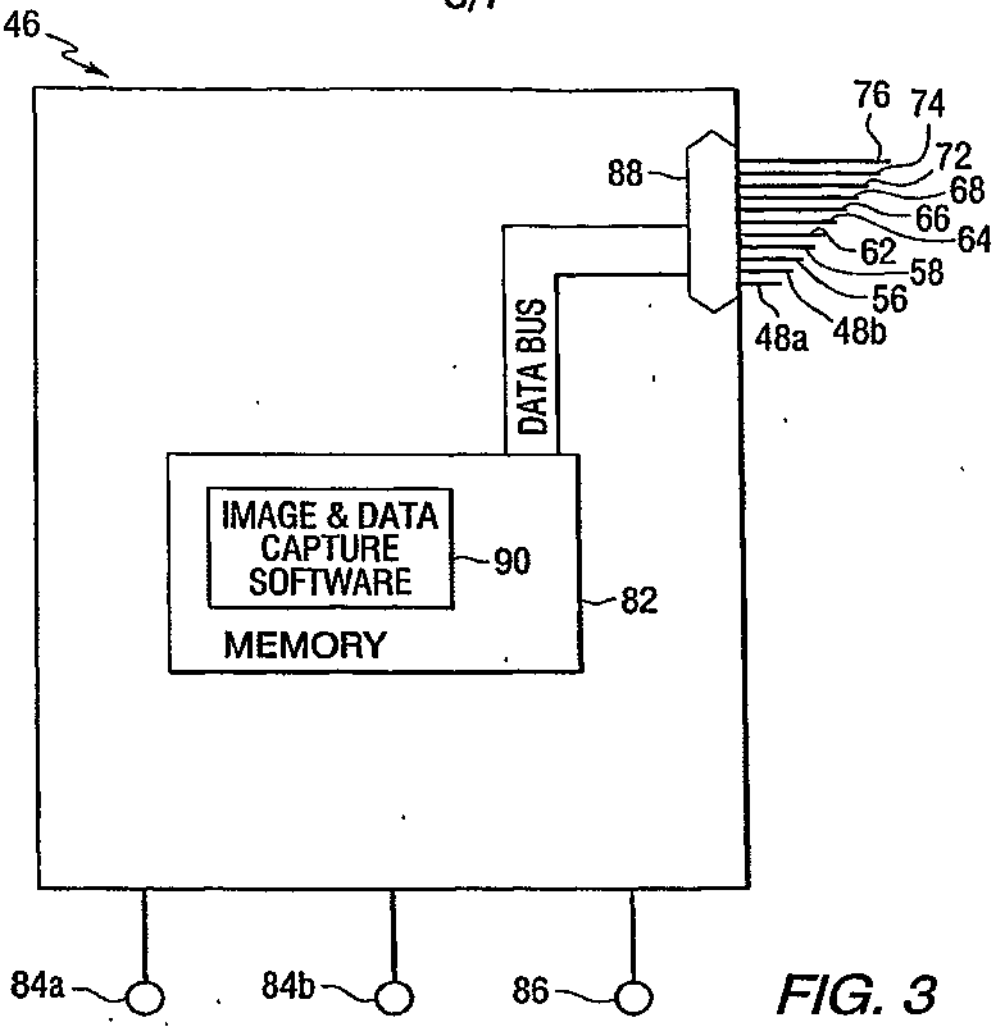

46
76
74
72
68
66
64
62
58
56
88
48a
48b
DATA BUS
IMAGE & DATA CAPTURE SOFTWARE
90
82
MEMORY
84a
84b
86

FIG. 3

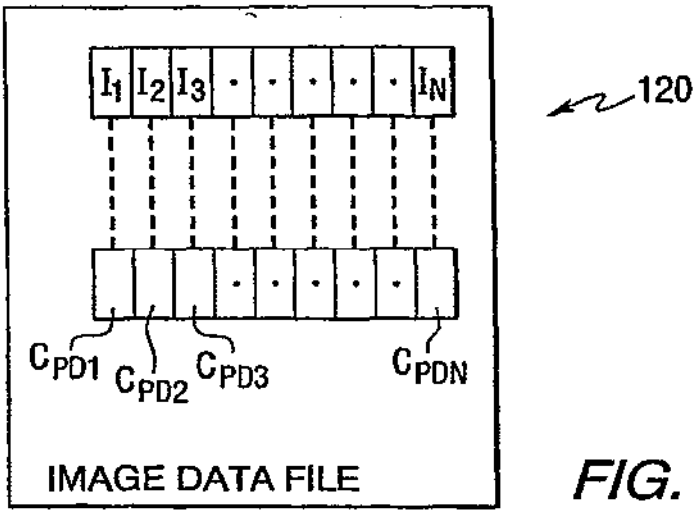

I_1 I_2 I_3 · · · · · I_N
120
C_{PD1} C_{PD2} C_{PD3} C_{PDN}
IMAGE DATA FILE

FIG. 4

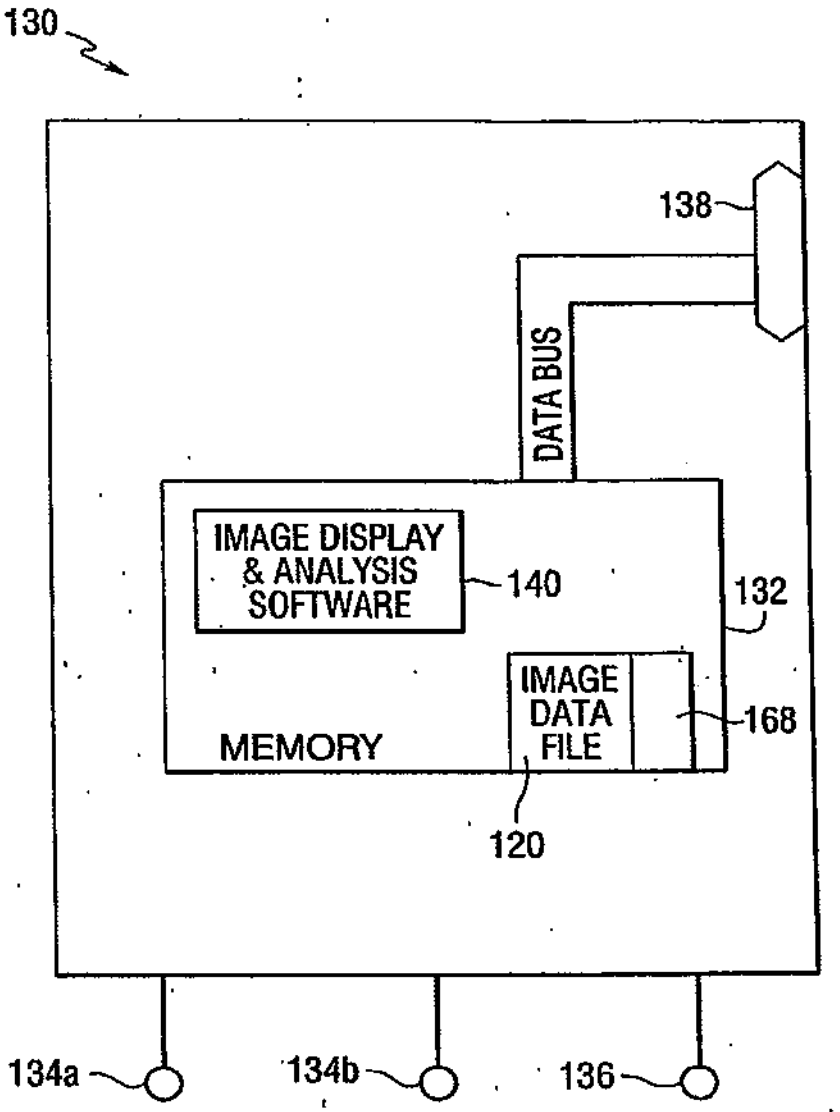

130
138
DATA BUS
IMAGE DISPLAY & ANALYSIS SOFTWARE
140
132
IMAGE DATA FILE
168
MEMORY
120
134a
134b
136

FIG. 5

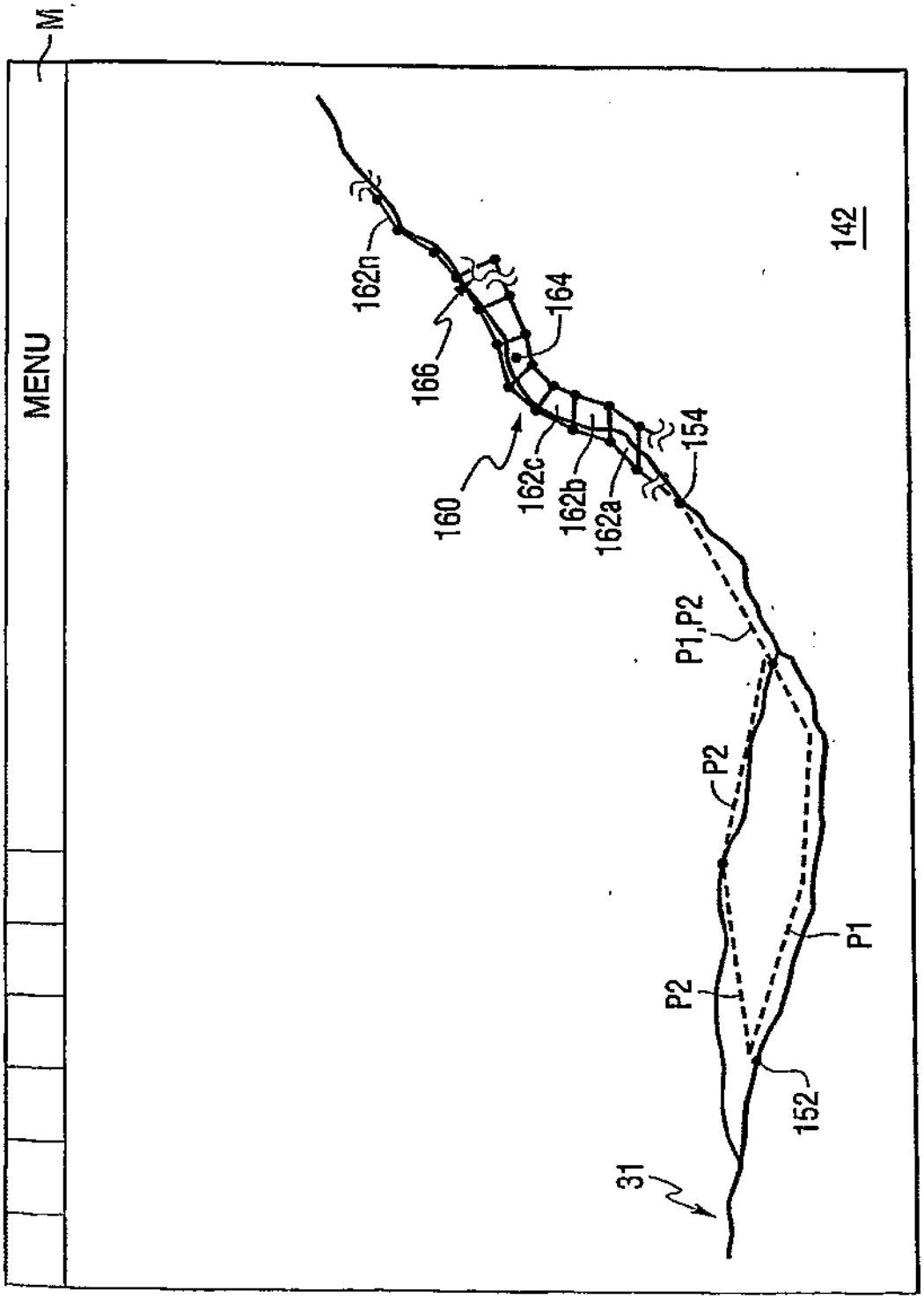

M
MENU
142
162n
164
166
160
162c
162b
162a
154
P1,P2
P2
P1
P2
152
31

FIG. 6

WO 2004/044692 PCT/US2003/035528

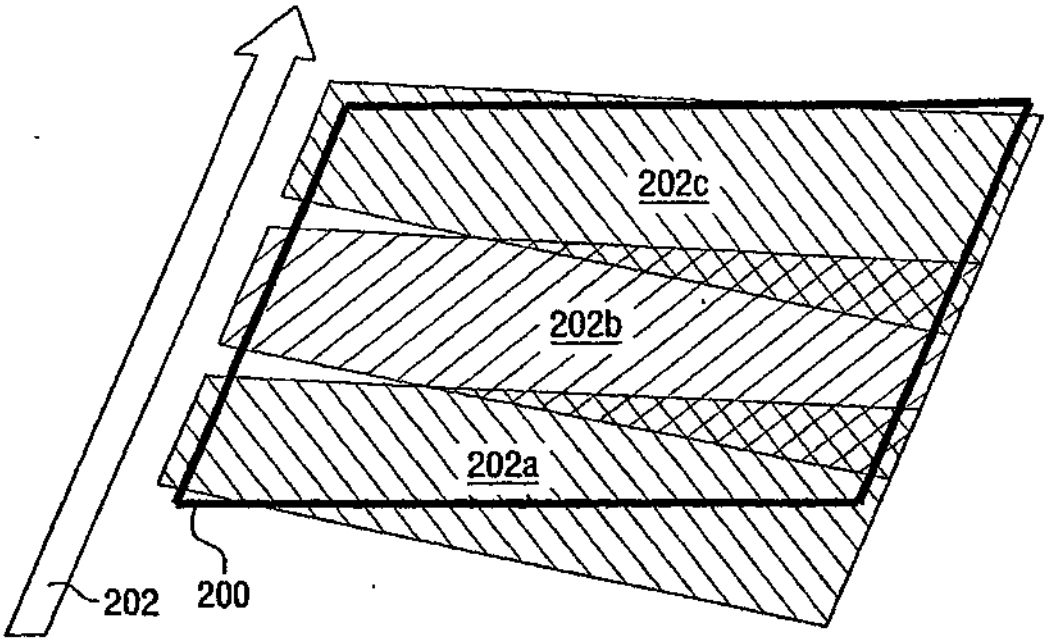


FIG. 7

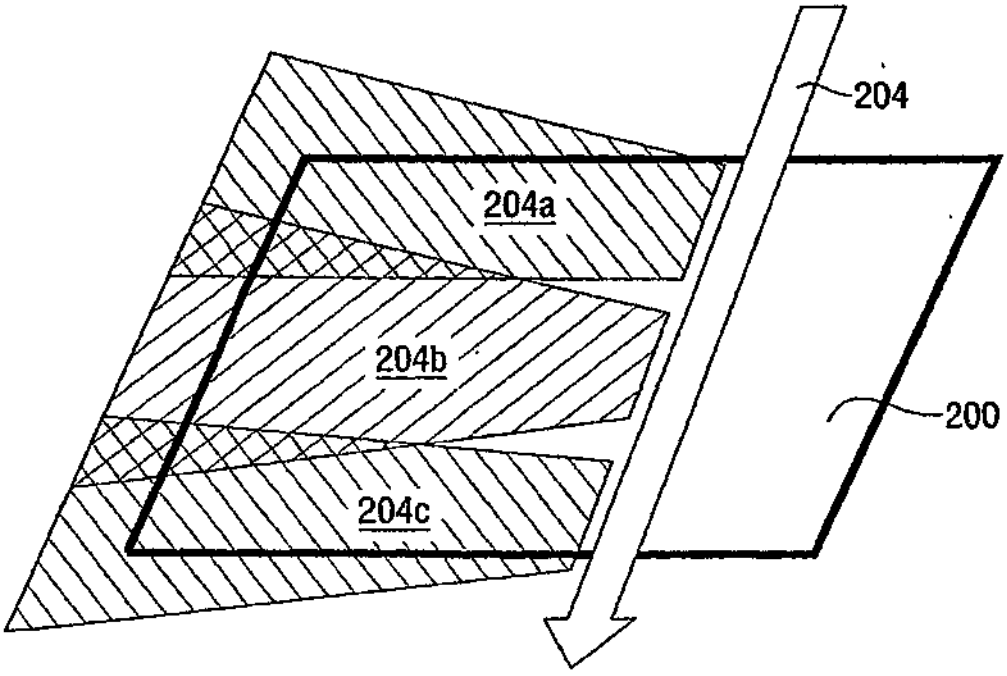


FIG. 8

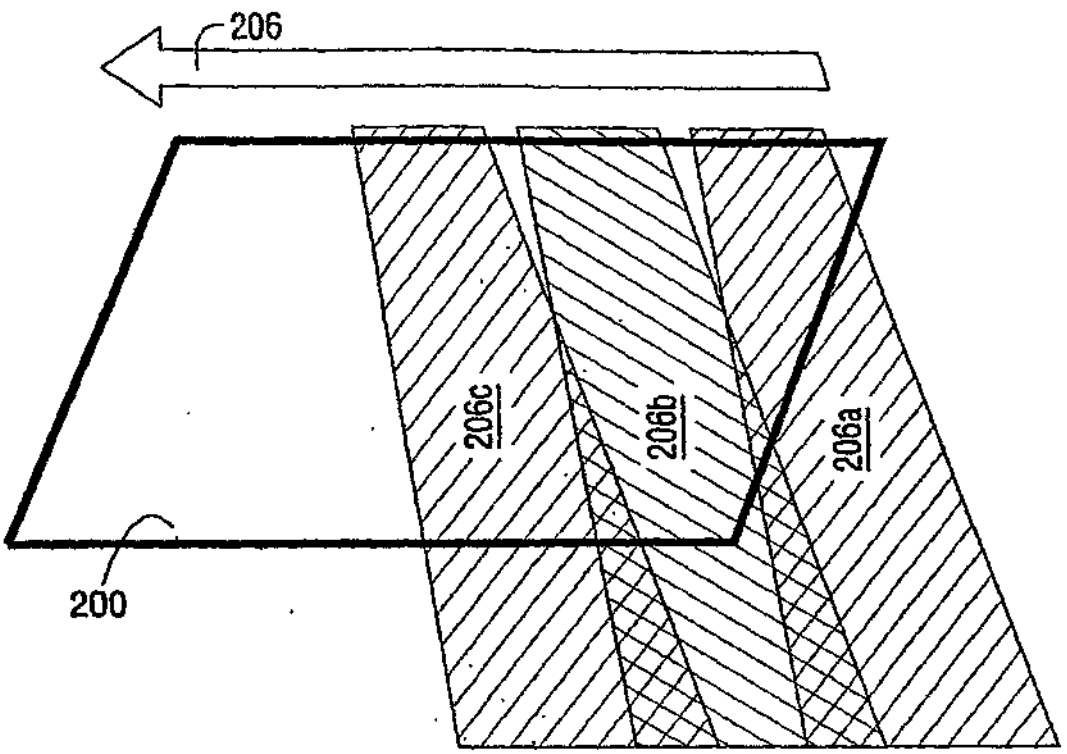


FIG. 9

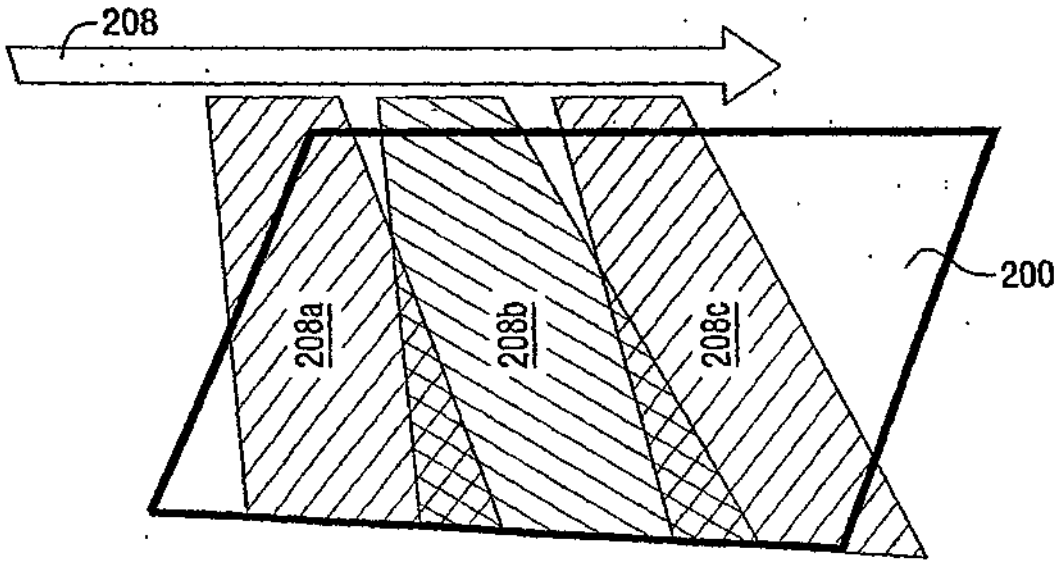


FIG. 10

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 418 402 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
21.06.2006 Bulletin 2006/25

(51) Int Cl.:
G01C 11/02 *(2006.01)*

(21) Application number: **03025702.6**

(22) Date of filing: **07.11.2003**

(54) **Method and apparatus for capturing, geolocating and measuring oblique images**

Verfahren und Gerät zur Erfassung, Geolokalisierung und Vermessung schräg aufgenommener Bilder

Procédé et appareil pour l'acquisition, géolocalisation et mesurage d'images obliques

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

(30) Priority: **08.11.2002 US 425275 P**

(43) Date of publication of application:
12.05.2004 Bulletin 2004/20

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(56) References cited:
WO-A-99/18732 **US-A- 3 153 784**

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EP 1 418 402 B1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

[0002] The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

[0003] Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

[0004] Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

[0005] Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

[0006] Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectfified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

[0007] Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

[0008] Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

[0009] Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which meas-

urements can be made and reducing the accuracy of any such measurements.

[0010] Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein. WO 99/18732 A1 discloses a system and method for capturing, geolocating and measuring oblique images comprising an image capturing device, a geolocating device, a computer system and image and data acquiring software, which associates the image data to the geolocating signal data.

Object of the invention

[0011] Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique images.

[0012] Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

[0013] Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

[0014] The present invention provides a system according to claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby;

FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1;

FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2;

FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1;

FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1;

FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement of and between objects depicted in such an image;

FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention;

FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

[0016] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

[0018] Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

[0019] Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

[0020] Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as

will be more particularly described hereinafter.

[0021] As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A_1 and A_2, and are mounted to platform 20 such that axes A_1 and A_2 are each at an angle of declination θ relative to a horizontal plane *P*. Declination angle θ is virtually any oblique angle, but is preferably from approximately 20° (twenty degrees) to approximately 60° (sixty degrees) and is most preferably from approximately 40° (forty degrees) to approximately 50° (fifty degrees).

[0022] GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0023] INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0024] Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

[0025] Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0026] Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

[0027] Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

[0028] As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer, includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

[0029] Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

[0030] In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

[0031] Image and data acquiring software 90 decodes

as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

[0032] Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

[0033] As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

[0034] Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

[0035] As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point *N* of orthogonal image 102. Thus, the exact geo-location of the nadir point *N* of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir point *N* of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

[0036] When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination θ of the primary axes A_1 *and* A_2 of image-capturing devices 32a and 32b, respectively.

[0037] It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

[0038] Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I_1, I_2, ..., I_n corresponding to captured oblique images, and the positional data C_{PD1}, C_{PD2}, ... , C_{PDn} corresponding thereto.

[0039] Image files I_1, I_2, ..., I_n of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data C_{PD1}, C_{PD2}, ..., C_{PDn} which is also stored as computer-readable data. Alternatively, positional data C_{PD1}, C_{PD2}, ..., C_{PDn} is embedded within the corresponding image files I_1, I_2, ..., I_n in known manner. Image data files 120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

[0040] Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with image display and analysis software 140 being executed by image display and measurement

computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

[0041] In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images I_1, I_2, ..., I_n of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions C_{PD1}, C_{PD2}, ..., C_{PDn} corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

[0042] It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or fitted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions C_{PD1}, C_{PD2}, ..., C_{PDn} of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

[0043] Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars *M*, or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

[0044] After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel 154.

[0045] When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions C_{PD1}, C_{PD2}, ..., C_{PDn} of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

[0046] The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions C_{PD1}, C_{PD2}, ..., C_{PDn} of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

[0047] As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142 corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 152 which, for simplicity, corresponds to center *C* (Fig. 1) of oblique image 104a. As shown in Fig. 1, line 106 extends along horizontal plane *G* from a point 108 thereon that is directly below image-capturing device 32a to the center *C* of the near border or edge 108 of oblique image 104a. An extension of primary axis A_1 intersects with center *C*. Angle ∅ is the angle formed between line 106 the extension of primary axis A_1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center *C*, and having sides 106, the extension of primary axis A_1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

[0048] Ground plane *G* is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle ∅ and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A_1) and remaining other side of the right trian-

gle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center *C* of oblique image 104a to be determined by image display and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

[0049] The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

[0050] It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path *P1* or a path *P2* that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected therewith.

[0051] It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths *P1* and *P2*, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths *P1* and *P2* also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

[0052] For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

[0053] In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A_1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

[0054] For example, if surface 31 slopes upward between nadir point *N* and center *C* at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center *C* is fifteen feet higher than nadir point *N* and with a declination angle θ equal to 40° (forty degrees), the calculated location of center *C* would be off by approximately 17.8 feet without correction for the change in elevation between the points.

[0055] As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant inaccuracies in the measurement of and between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, sur-

vey data, and various other sources.

[0056] Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc, within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

[0057] To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

[0058] More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

[0059] Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

[0060] Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

[0061] The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

[0062] Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed above, and that elevation is used within the location calculation.

[0063] Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process

known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest - how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

[0064] The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

[0065] The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

[0066] More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180° (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

[0067] If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

[0068] As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

[0069] The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

[0070] A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially constant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-

inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

[0071] It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

[0072] In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary.

[0073] In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

[0074] In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

[0075] In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180° (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other.

[0076] While the present invention has been described as having a preferred design, the invention can be further modified within the scope of the claims. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended claims.

Claims

1. A computerized system for displaying, geolocating, and making measurements based upon captured oblique images, comprising:

   a computer system (130) having a memory (132);
   an image and data file (120) accessible by said system (130) and including a plurality of image files corresponding to a plurality of captured oblique images, said image and data file (120) further including positional data corresponding to said plurality of image files; and
   image display and analysis software (140) executed by said system (130) for reading said image and data file (120) and displaying at least a portion of the captured oblique images as a displayed oblique image, said image display and analysis software (140) calculating the geo-locations of two or more selected points within said displayed oblique image based at least in part upon said positional data, said image display and analysis software (140) calculating a separation distance between any two or more selected points within said displayed oblique image;
   characterized by
   a ground plane data file representing a tessellated ground plane (160), said ground plane data file providing data to said image display and analysis software (140), said ground plane data file representing a tessellated ground plane that closely approximates at least a portion of the terrain depicted within said captured oblique images, said tessellated ground plane further comprising a plurality of interconnected images, said tessellated ground plane further comprising a plurality of interconnected facets (162a, 162b, 162c, ...), each of said plurality of facets having a respective pitch and slope, said ground plane data file comprising a plurality of vertices, each of said plurality of vertices having respective elevations and defining corners of said plurality of interconnected facets (162a, 162b, 162c, ...), two of said plurality of vertices shared by each of said interconnected facets; and
   said image display and analysis software (140) identifying which of said plurality of facets corresponds to a selected point on said displayed oblique image, and calculating an elevation of said selected point dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point, said image display and analysis software (140) using said

calculated elevation for calculating said separation distance between said selected point and one or more further selected points.

2. The system of claim 1, wherein said image display and analysis software (140) calculating said geo-locations only as needed.

3. The system of claim 1 or 2, wherein said image display and analysis software (140) calculates a height of an object within said displayed oblique image by calculating the separation distance between two or more selected points.

4. The system of one of the claims 1 to 3, wherein said tessellated ground plane (160) is superimposed upon and fit to said displayed oblique image.

5. The system of one of the claims 1 to 4, wherein said image display and analysis software (140) includes user-selectable measuring modes accessible through at least one of pull-down menus, toolbars and keyboard commands.

6. The system of one of the claims 1 to 5, wherein each of said images were captured by an image-capturing device (32a, 32b) and at respective image capturing events, said positional data of said image and data file including:

time data representing the time of each image-capturing event;
location data representing the location of the image-capturing device (32a, 32b) at each image-capturing event;
orientation data representing the orientation of the image-capturing device (32a, 32b) at each image-capturing event;
correction data representing correction factors for the image-capturing device (32a, 32b); and
elevation data representing an average elevation of the surface captured by the image-capturing device (32a, 32b).

7. The system of claim 6, wherein said location data includes latitude, longitude, and altitude of the image-capturing apparatus (32a, 32b) at each image-capturing event.

8. The system of claim 6 or 7, wherein said orientation data includes roll, pitch, yaw and heading of said image-capturing device (32a, 32b) at each image-capturing event.

9. The system of one of the claims 6 to 8, wherein said image-capturing device (32a, 32b) is a camera and said correction data includes at least one of focal length, sensor size, aspect ratio, principal point offset, distortion, and pixel pitch.

10. The system of one of the claims 6 to 9, comprising:

an input device (134a, 134b) for selecting a starting point and an end point on the displayed oblique image; and
said image display and analysis software (140) for retrieving from said data file positional data corresponding to said starting point and said end point; for referencing said ground plane data file corresponding to said tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said tessellated ground plane closely matching a terrain of said displayed oblique image; for connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and for calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

11. The system of one of the claims 1 to 10, wherein said image display and analysis software (140) superimposes said tessellated ground plane upon said displayed oblique image.

12. The system of claim 10 or 11, comprising:

said input device (134a, 134b) for selecting one or more intermediate points on said displayed oblique image; and
said image display and analysis software (140) for retrieving from said data file positional data corresponding to said one or more intermediate points; for connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and for calculating the distance along said line segments between said starting and end points.

13. The system of one of the claims 1 to 12, wherein said plurality of facets (162a, 162b, 162c, ...) each correspond to equal areas of said displayed oblique image.

14. The system of one of the claims 1 to 13, wherein said plurality of facets (162a, 162b, 162c, ...) each includes an equal number of pixels of said displayed oblique image.

15. The system of one of the claims 1 to 14, comprising an input device (134a, 134b) for selecting one or

more intermediate points on said displayed oblique image; and the said image display and analysis software (140) for retrieving the positional data corresponding to said intermediate points.

16. The system of one of the claims 1 to 15, wherein said separation distance comprises a distance between two or more selected points, a height difference between two or more selected points, a difference in elevation of two or more selected points, and an area encompassed by at least three points.

17. The system of one of the claims 1 to 16, comprising:

an image-capturing device (32a, 32b), said image-capturing device (32a, 32b) capturing oblique images at image-capturing events, said image capturing device (32a, 32b) issuing image-data signals corresponding to captured images;
at least one geo-locating device (34, ..., 44), each said at least one geo-locating device (34, ..., 44) issuing a corresponding at least one geo-locating signal, each said at least one geo-locating signal being indicative at least in part of a geo-location of said image-capturing device (32a, 32b) during each image capturing event; and
a computer system (46) receiving and storing said image-data signals and said at least one geo-locating signal; and
image and data acquiring software (90) reading said image-data signals and said at least one geo-locating signal, said software (90) associating each said image-data signal with a corresponding said at least one geo-locating signal for each image-capturing event.

18. The system of claim 17, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise at least one of:

a clock (38) issuing to said image-capturing computer system (46) time data signals indicative of a time of each said image-capturing event;
a global-positioning system (GPS) receiver (34) receiving GPS signals and issuing to said image-capturing computer system (46) location data signals indicative of a longitude and latitude of said image-capturing device (32a, 32b) at each said image-capturing event;
an inertial navigation unit (36) issuing to said image-capturing computer system (46) velocity data signals indicative of a velocity of said image-capturing device (32a, 32b) at each said image-capturing event;
a gyroscope (40) issuing to said image-capturing computer system (46) a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device (32a, 32b) at each said image-capturing event;
a compass (42) issuing to said image-capturing computer system (46) heading data signals indicative of a heading of said image-capturing device (32a, 32b) at each said image-capturing event; and
an altimeter (44) issuing to said image-capturing computer system (46) altitude data signals indicative of an altitude of said image-capturing device (32a, 32b) at each said image-capturing event.

19. The system of claim 17 or 18, further comprising correction data indicative of characteristics of said image-capturing device (32a, 32b) including focal length, sensor size, radial distortion, principal point offset and alignment, said image and data acquiring software (90) utilizing said correction data to correct captured images.

20. The system of one of the claims 17 to 19, further comprising an output data file created by said image and data acquiring software (90), said output data file including a plurality of image files and positional data corresponding to each of said plurality of image files.

21. The system of one of the claims 17 to 20, further comprising a platform (20) carrying said image-capturing device (32a, 32b) a predetermined distance above a surface of interest.

22. The system of claim 21 wherein said image-capturing device (32a, 32b) captures oblique images of an area of interest as said oblique images by:

subdividing the area (200) of interest into a plurality of sectors (202a, 202b, 202c);
guiding said platform (20) along a first path (202) to thereby target one or more target sectors with said image-capturing device (32a, 32b);
capturing with said image-capturing device (32a, 32b) one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective;
guiding said platform (20) along a second path (204) to thereby target said target sectors;
capturing with said image-capturing device (32a, 32b) one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective;
repeating said guiding and capturing steps along paths substantially parallel to and spaced

apart from said first and second paths (202, 204) and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and
recording positional data indicative of a geo-location of said image-capturing device (32a, 32b) at each image-capturing event.

23. The system of claim 22, wherein said second path (204) is substantially parallel relative to and 180° (one-hundred and eighty degrees) from said first path (202).

24. The system of claim 23, wherein said second path (204) is also spaced apart from said first path (202).

25. The system of one of the claims 22 to 24, wherein
said platform (20) is guided along a third path (206) to thereby target one or more target sectors with said image-capturing device (32a, 32b), said third path (206) being substantially perpendicular to said first and second paths (202, 204);
said image-capturing device (32a, 32b) captures one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a third perspective; wherein
said platform (20) is guided and said image-capturing device (32a, 32b) captures said oblique images along paths substantially parallel to and spaced apart from said third path (306); and
said image-capturing device (32a, 32b) captures one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

26. The system of claim 25, wherein
said platform (20) is guided along a fourth path (208) to thereby target one or more target sectors with said image-capturing device (32a, 32b), said fourth path (208) being substantially parallel with said third path (206) and 180° (one-hundred and eighty degrees) from said third path (206);
said image-capturing device (32a, 32b) captures one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and
said guiding and capturing steps are repeated along paths substantially parallel to and spaced apart from said fourth path (208) and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

27. The system of claim 26, wherein said fourth path (208) is also spaced apart from said third path (206).

Patentansprüche

1. Computerisiertes System zum Darstellen, Erdpositionsbestimmen und Durchführen von Messungen auf der Grundlage aufgenommener schräger Bilder, umfassend:

ein Computersystem (130) mit einem Speicher (132);
eine Bild- und Datendatei (120), auf die durch das System (130) zugegriffen werden kann, und die eine Vielzahl von Bilddateien umfasst, die einer Vielzahl aufgenommener schräger Bilder entsprechen, wobei die Bild- und Datendatei (120) weiterhin Positionsdaten umfasst, die zu der Vielzahl von Bilddateien gehören; und
eine Bildanzeige- und -analyse-Software (140), die von dem System (130) zum Lesen der Bild- und Datendatei (120) und zum Anzeigen mindestens eines Teils der aufgenommenen schrägen Bilder als ein angezeigtes schräges Bild ausgeführt wird, wobei die Bildanzeige- und -analyse-Software (140) die Erdpositionen von zwei oder mehr ausgewählten Punkten zumindest teilweise auf der Grundlage der Positionsdaten berechnet, wobei die Bildanzeige- und -analyse-Software (140) einen Abstand zwischen allen zwei oder mehr ausgewählten Punkten innerhalb des angezeigten schrägen Bildes berechnet;
gekennzeichnet durch
eine Grundebenendatendatei eine mosaikartige Grundebene (160) darstellt, wobei die Grundebenendatendatei der Bildanzeige- und -analyse-Software (140) Daten bereitstellt, wobei die Grundebenendatendatei eine mosaikartige Grundebene darstellt, welche zumindest einen Teil des innerhalb des aufgenommenen schrägen Bildes dargestellten Geländes nah annähert, wobei die mosaikartige Grundebene weiterhin eine Vielzahl zusammenhängender Bilder umfasst, wobei die mosaikartige Grundebene weiterhin eine Vielzahl zusammenhängender Facetten (162a, 162b, 162c, ...) umfasst, wobei jede der Vielzahl von Facetten einen entsprechende Abstand und Steigung aufweist, wobei die Grundebenendatendatei eine Vielzahl von Eckpunkten umfasst, wobei jeder der Vielzahl von Eckpunkten entsprechende Höhelagen aufweist und Ecken der Vielzahl der zusammenhängenden Facetten (162a, 162b, 162c, ...) definiert, wobei jede der zusammenhängenden Facetten sich zwei aus der Vielzahl der Facetten teilt; und
die Bildanzeige- und -analyse-Software (140), die identifiziert, welche der Vielzahl der Facetten zu einem ausgewählten Punkt auf dem angezeigten schrägen Bild gehört, und die eine Höhe

des ausgewählten Punkts abhängig zumindest teilweise von der Höhenlage der Eckpunkte derjenigen Facette berechnet, die zu dem ausgewählten Punkt gehört, wobei die Bildanzeige- und -analyse-Software (140) die berechnete Höhenlage zum Berechnen des Abstandes zwischen dem ausgewählten Punkt und einem oder mehreren weiteren ausgewählten Punkten verwendet.

2. System nach Anspruch 1, wobei die Bildanzeige- und -analyse-Software (140) die Erdpositionen nur bei Bedarf berechnet.

3. System nach Anspruch 1 oder 2, wobei die Bildanzeige- und -analyse-Software (140) eine Höhe eines innerhalb des angezeigten schrägen Bildes vorhandenen Objekts berechnet, und zwar durch Berechnen des Abstandes zwischen zwei oder mehr ausgewählten Punkten.

4. System nach einem der Ansprüche 1 bis 3, wobei die mosaikartige Grundebene (160) dem angezeigten schrägen Bild überlagert und angepasst ist.

5. System nach einem der Ansprüche 1 bis 4, wobei die Bildanzeige- und -analyse-Software (140) nutzerauswählbare Messmodi umfasst, auf die durch Pulldown-Menüs, Symbolleisten und / oder Tastaturkommandos zugegriffen werden kann.

6. System nach einem der Ansprüche 1 bis 5, wobei jedes der Bilder von einer Bildaufnahmevorrichtung (32a, 32b) und zu entsprechenden Bildaufnahmeereignissen aufgenommen wurden, wobei die Positionsdaten der Bild- und Datendatei umfassen:

Zeitdaten, die der Zeit jedes Bildaufnahmeereignisses entsprechen;
Positionsdaten, die dem Ort der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis entsprechen;
Ausrichtungsdaten, die der Ausrichtung der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis entsprechen;
Korrekturdaten, die Korrekturfaktoren für die Bildaufnahmevorrichtung (32a, 32b) entsprechen; und
Höhenlagendaten, die einer durchschnittlichen Höhenlage der durch die Bildaufnahmevorrichtung (32a, 32b) aufgenommenen Oberfläche entsprechen.

7. System nach Anspruch 6, wobei die Positionsdaten einen Breitengrad, einen Längengrad und eine Höhenlage der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis umfassen.

8. System nach Anspruch 6 oder 7, wobei die Ausrichtungsdaten ein Rollen, Stampfen, Gieren und eine Ausrichtung der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis umfassen.

9. System nach einem der Ansprüche 6 bis 8, wobei die Bildaufnahmevorrichtung (32a, 32b) eine Kamera ist und die Korrekturdaten eine Brennweite, eine Sensorgröße, ein Bildseitenverhältnis, einen Hauptpunktversatz, eine Verzerrung und / oder einen Bildpunktabstand umfassen.

10. System nach einem der Ansprüche 6 bis 9, umfassend:

eine Eingabevorrichtung (134a, 134b) zum Auswählen eines Anfangspunkts und eines Endpunkts auf dem angezeigten schrägen Bild; und die Bildanzeige- und -analyse-Software (140) zum Auslesen von Positionsdaten aus der Datendatei, die zu dem Anfangspunkt und dem Endpunkt gehören; zum Referenzieren der Grundebenendatei, die zur mosaikartigen Grundebene gehört, die eine Vielzahl von Facetten aufweist, wobei jede der Facetten einen zugehörige Abstand und Steigung aufweist, wobei die mosaikartige Grundebene mit einem Gelände des angezeigten schrägen Bildes nahezu übereinstimmt; zum Verbinden der Anfangs- und Endpunkte mit Linienabschnitten, wobei die Linienabschnitte an den Abstand und die Steigung der Facetten angepasst sind, um dem Gelände zu folgen; und zum Berechnen des geraden Abstands entlang der Liniensegmente zwischen den Anfangs- und Endpunkten, wobei der Abstand und die Steigung der Facetten berücksichtige werden.

11. System nach einem der Ansprüche 1 bis 10, wobei die Bildanzeige- und - analyse-Software (140) die mosaikartige Grundebene auf das angezeigte schräge Bild überlagert.

12. System nach Anspruch 10 oder 11, umfassend:

die Eingabevorrichtung (134a, 134b) zum Auswählen eines oder mehrerer Zwischenpunkte auf dem angezeigten schrägen Bild; und
die Bildanzeige- und -analyse-Software (140) zum Auslesen von Positionsdaten aus der Datendatei, die zu dem einen oder den mehreren Zwischenpunkten gehören; zum Verbinden benachbarter Zwischenpunkte miteinander und zum Verbinden des Anfangs- und Endpunkts mit benachbarten Zwischenpunkten durch Linienabschnitte, wobei die Linienabschnitte an den Abstand und die Steigung der Facetten angepasst sind, um dem Gelände zu folgen; und zum

Berechnen des Abstands entlang der Liniensegmente zwischen dem Anfangs- und dem Endpunkt.

13. System nach einem der Ansprüche 1 bis 12, wobei die Vielzahl der Facetten (162a, 162b, 162c, ...) jeweils gleichen Flächen des angezeigten schrägen Bildes entsprechen.

14. System nach einem der Ansprüche 1 bis 13, wobei die Vielzahl der Facetten (162a, 162b, 162c, ...) jeweils eine gleiche Zahl von Bildpunkten des angezeigten schrägen Bildes umfasst.

15. System nach einem der Ansprüche 1 bis 14, umfassend eine Eingabevorrichtung (134a, 134b) zum Auswählen eines oder mehrerer Zwischenpunkte auf dem angezeigten schrägen Bild; und die Bildanzeige- und -analyse-Software (140) zum Auslesen der Positionsdaten, die zu den Zwischenpunkten gehören.

16. System nach einem der Ansprüche 1 bis 15, wobei der Abstand einen Abstand zwischen zwei oder mehr ausgewählten Punkten, einen Höhenunterschied zwischen zwei oder mehr ausgewählten Punkten, einen Höhenlagenunterschied zwischen zwei oder mehr ausgewählten Punkten und eine durch zumindest drei Punkte umfasste Fläche umfasst.

17. System nach einem der Ansprüche 1 bis 16, umfassend:

eine Bildaufnahmevorrichtung (32a, 32b), wobei die Bildaufnahmevorrichtung (32a, 32b) schräge Bilder zu Bildaufnahmeereignissen aufnimmt, wobei die Bildaufnahmevorrichtung (32a, 32b) Bilddatensignale ausgibt, die den aufgenommenen Bildern entsprechen;
mindestens eine Erdpositionsbestimmungsvorrichtung (34, ..., 44), wobei die mindestens eine Erdpositionsbestimmungsvorrichtung (34, ..., 44) zumindest ein zugehöriges Erdpositionsbestimmungssignal ausgibt, wobei jedes der mindestens einen Erdpositionsbestimmungssignale zumindest teilweise eine Erdposition der Bildaufnahmevorrichtung (32a, 32b) während jedes Bildaufnahmeereignisses anzeigt; und
ein Computersystem (46), das Bilddatensignale und das mindestens eine Erdpositionsbestimmungssignal empfängt und speichert;
Bild- und Datenaufnahme-Software (90), welche die Bilddatensignale und das mindestens eine Erdpositionsbestimmungssignal liest, wobei die Software (90) jedes Bilddatensignal mit einem zugehörigen mindestens einen Erdpositionsbestimmungssignal für jedes Bildaufnahmeereignis verknüpft.

18. System nach Anspruch 17, wobei die mindestens eine Erdpositionsbestimmungsvorrichtung und das mindestens ein Erdpositionsbestimmungssignal entsprechend umfassen:

eine Uhr (38), die Zeitdatensignale an das bildaufnehmende Computersystem (46) ausgibt, die einen Zeitpunkt jedes Bildaufnahmeereignisses angeben;
einen GPS-Empfänger (34), der GPS-Signale empfängt und Positionsdatensignale an das bildaufnehmende Computersystem (46) ausgibt, die einen Längengrad und einen Breitengrad der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis angeben;
eine Trägheitsnavigationseinheit (36), die Geschwindigkeitsdatensignale an das bildaufnehmende Computersystem (46) ausgibt, die eine Geschwindigkeit der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis angeben;
ein Gyroskop (40), das ein Stampfsignal, ein Rollsignal und ein Giersignal an das bildaufnehmende Computersystem (46) ausgibt, die ein entsprechendes Stampfen, Rollen und Gieren zu jedem Bildaufnahmeereignis angeben;
einen Kompass (42), der Ausrichtungsdatensignale an das bildaufnehmende Computersystem (46) ausgibt, die eine Ausrichtung der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis angeben; und / oder
einen Höhenmesser (44), der Höhenlagendatensignale an das bildaufnehmende Computersystem (46) ausgibt, die eine Höhenlage der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis angeben.

19. System nach Anspruch 17 oder 18, weiterhin umfassend Korrekturdaten, die Eigenschaften der Bildaufnahmevorrichtung (32a, 32b) angeben, einschließlich Brennweite, Sensorgröße, radiale Verzerrung, Hauptpunktversatz und Ausrichtung, wobei die Bild- und Datenaufnahme-Software (90) die Korrekturdaten verwendet, um aufgenommene Bilder zu korrigieren.

20. System nach einem der Ansprüche 17 bis 19, weiterhin umfassend eine Ausgabedatendatei, die durch die Bild- und Datenaufnahme-Software (90) erzeugt wird, wobei die Ausgabedatendatei eine Vielzahl von Bilddateien und zu der Vielzahl von Bilddateien gehörige Positionsdaten umfasst.

21. System nach einem der Ansprüche 17 bis 19, weiterhin umfassend eine Plattform (20) zum Tragen der Bildaufnahmevorrichtung (32a, 32b) um einen

vorbestimmten Anstand oberhalb der von Interesse seienden Oberfläche.

22. System nach Anspruch 21, wobei die Bildaufnahmevorrichtung (32a, 32b) schräge Bilder einer von Interesse seienden Fläche als die schrägen Bilder aufnimmt mittels:

Unterteilen der von Interesse seienden Fläche (200) in eine Vielzahl von Sektoren (202a, 202b, 202c);
Führen der Plattform (20) entlang eines ersten Pfads (202), um so mit der Bildaufnahmevorrichtung (32a, 32b) auf einen oder mehrere Zielsektoren zu zielen;
Aufnehmen eines oder mehrerer schräger Bilder mit der Bildaufnahmevorrichtung (32a, 32b), um damit eine Gesamtheit jedes der Zielsektoren mit schrägen Bildern, die aus einer ersten Perspektive aufgenommen werden, abzudekken;
Führen der Plattform (20) eines zweiten Pfads (204), um so auf die Zielsektoren zu zielen;
Aufnehmen eines oder mehrerer schräger Bilder mit der Bildaufnahmevorrichtung (32a, 32b), um damit eine Gesamtheit jedes der Zielsektoren mit schrägen Bildern, die aus einer zweiten Perspektive aufgenommen werden, abzudekken;
Wiederholen der Führungs- und Aufnahmeschritte entlang von Pfaden, die im wesentlichen parallel und beabstandet von dem ersten und zweiten Pfad (202, 204) liegen, und Aufnehmen eines oder mehrerer schräger Bilder, um damit eine Gesamtheit jedes der Vielzahl der Zielsektoren mit schrägen Bilder, die sowohl aus der ersten als auch aus der zweiten Perspektive aufgenommen werden, abzudecken; und
Aufnehmen von Positionsdaten, die eine Erdposition der Bildaufnahmevorrichtung (32a, 32b) zu jedem Bildaufnahmeereignis anzeigen.

23. System nach Anspruch 22, wobei der zweite Pfad (204) im wesentlichen parallel zum und um 180° (einhundertachtzig Grad) gedreht zum ersten Pfad (202) liegt.

24. System nach Anspruch 23, wobei der zweite Pfad (204) vom ersten Pfad (202) auch beabstandet ist.

25. System nach einem der Ansprüche 22 bis 24, wobei die Plattform (20) entlang eines dritten Pfads (206) geführt wird, um so mit der Bildaufnahmevorrichtung (32a, 32b) auf einen oder mehrere Zielsektoren zu zielen, wobei der dritte Pfad (206) im wesentlichen senkrecht zum dem ersten und dem zweiten Pfad (202, 204) liegt;
die Bildaufnahmevorrichtung (32a, 32b) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes Zielsektors mit schrägen Bildern, die aus einer dritten Perspektive aufgenommen werden, abzudecken; wobei
die Plattform (20) geführt wird und die Bildaufnahmevorrichtung (32a, 32b) die schrägen Bilder entlang von Pfaden aufnimmt, der im wesentlichen parallel und beabstandet von dem dritten Pfad (306) liegen; und
wobei die Bildaufnahmevorrichtung (32a, 32b) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes aus der Vielzahl der Zielsektoren mit schrägen Bildern, die aus der dritten Perspektive aufgenommen werden, abzudecken.

26. System nach Anspruch 25, wobei
die Plattform (20) entlang eines vierten Pfads (208) geführt wird, um so mit der Bildaufnahmevorrichtung (32a, 32b) auf einen oder mehrere Zielsektoren zu zielen, wobei der vierte Pfad (208) im wesentlichen parallel zum und um 180° (einhundertachtzig Grad) gedreht zum dritten Pfad (206) liegt;
die Bildaufnahmevorrichtung (32a, 32b) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes Zielsektors mit schrägen Bildern, die aus einer vierten Perspektive aufgenommen werden, abzudecken; und
die Führungs- und Aufnahmeschritte entlang von Pfaden wiederholt werden, die im wesentlichen parallel zu und beabstandet von dem vierten Pfad (208) liegen, und Aufnehmen eines oder mehrerer schräger Bilder, um damit eine Gesamtheit jedes der Vielzahl der Zielsektoren mit schrägen Bilder, die aus der vierten Perspektive aufgenommen werden, abzudecken.

27. System nach Anspruch 26, wobei der vierte Pfad (208) von dem dritten Pfad (206) auch beabstandet ist.

Revendications

1. Système numérisé destiné à afficher, géolocaliser et faire des mesures basées sur des images obliques capturées, comprenant :

un système d'ordinateur (130) comportant une mémoire (132) ;
un fichier (120) d'images et de données accessible audit système (130) et comprenant une pluralité de fichiers d'images correspondant à une pluralité d'images obliques capturées, ledit fichier (120) d'images et de données comprenant en outre des données de position correspondant à ladite pluralité de fichiers d'images ; et
un logiciel (140) d'affichage et d'analyse d'ima-

ges exécuté par ledit système (130) pour lire ledit fichier (120) d'images et de données et afficher au moins une partie des images obliques capturées en tant qu'image oblique affichée, ledit logiciel (140) d'affichage et d'analyse d'images calculant les géolocalisations de deux ou de plus de deux points sélectionnés dans ladite image oblique affichée en se basant au moins en partie sur lesdites données de position, ledit logiciel (140) d'affichage et d'analyse d'images calculant une distance de séparation entre deux quelconques des deux ou plus de deux points sélectionnés dans ladite image oblique affichée ;

caractérisé par

un fichier de données de plan de sol représentant un plan de sol (160) en mosaïque, ledit fichier de données de plan de sol fournissant des données audit logiciel (140) d'affichage et d'analyse d'images, ledit fichier de données de plan de sol représentant un plan de sol en mosaïque qui approxime étroitement au moins une partie du terrain décrit dans lesdites images obliques capturées, ledit plan de sol en mosaïque comprenant en outre une pluralité d'images interconnectées, ledit plan de sol en mosaïque comprenant en outre une pluralité de facettes interconnectées (162a, 162b, 162c, ...), chacune des facettes de ladite pluralité ayant un pas et une pente respectifs, ledit fichier de données de plan de sol comprenant une pluralité de sommets, chacun des sommets de ladite pluralité ayant des élévations respectives et définissant des coins de ladite pluralité de facettes interconnectées (162a, 162b, 162c, ...), deux des sommets de ladite pluralité étant partagés par chacune des facettes interconnectée ; et

ledit logiciel (140) d'affichage et d'analyse d'images identifiant laquelle des facettes de ladite pluralité correspond à un point sélectionné sur ladite image oblique affichée, et calculant une élévation dudit point sélectionné dépendant au moins en partie de l'élévation des sommets de la facette correspondant au point sélectionné, ledit logiciel (140) d'affichage et d'analyse d'images utilisant ladite élévation calculée pour calculer ladite distance de séparation entre ledit point sélectionné et un ou plusieurs autres points sélectionnés.

2. Système selon la revendication 1, dans lequel ledit logiciel (140) d'affichage et d'analyse d'images ne calcule lesdites géolocalisations que si nécessaire.

3. Système selon la revendication 1 ou 2, dans lequel ledit logiciel (140) d'affichage et d'analyse d'images calcule une hauteur d'un objet dans ladite image oblique affichée en calculant la distance de séparation entre deux ou plus de deux points sélectionnés.

4. Système selon l'une des revendications 1 à 3, dans lequel ledit plan de sol en mosaïque (160) est superposé et s'adapte à ladite image oblique affichée.

5. Système selon l'une des revendications 1 à 4, dans lequel ledit logiciel (140) d'affichage et d'analyse d'images comprend des modes de mesure sélectionnables par l'utilisateur, accessibles par au moins soit des menus déroulants, soit des barres d'outils, soit des commandes de clavier.

6. Système selon l'une des revendications 1 à 5, dans lequel chacune desdites images a été capturée par un dispositif (32a, 32b) de capture d'image et lors d'événements respectifs de capture d'image, lesdites données de position dudit fichier d'images et de données comprenant :

des données de temps représentant l'instant de chaque événement de capture d'image ;
des données de localisation représentant la localisation du dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ;
des données d'orientation représentant l'orientation du dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ;
des données de correction représentant des facteurs de correction pour le dispositif (32a, 32b) de capture d'image ; et
des données d'élévation représentant une élévation moyenne de la surface capturée par le dispositif (32a, 32b) de capture d'image.

7. Système selon la revendication 6, dans lequel lesdites données de localisation comprennent la latitude, la longitude et l'altitude du dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image.

8. Système selon la revendication 6 ou 7, dans lequel lesdites données d'orientation comprennent le roulis, le tangage, le lacet et le cap dudit dispositif (32a, 32b) de capture d'image lors de chaque événement de capture d'image.

9. Système selon l'une des revendications 6 à 8, dans lequel ledit dispositif (32a, 32b) de capture d'image est une caméra et lesdites données de correction comprennent au moins soit la distance focale, soit la taille du capteur, soit le rapport d'allongement, soit le décalage du point principal, soit la distorsion, soit le pas des pixels.

10. Système selon l'une des revendications 6 à 9, comprenant :

un dispositif d'entrée (134a, 134b) destiné à sélectionner un point de départ et un point final sur l'image oblique affichée ; et
ledit logiciel (140) d'affichage et d'analyse d'images destiné à retrouver à partir dudit fichier de données les données de position correspondant audit point de départ et audit point final ; à référencer ledit fichier de données de plan de sol correspondant audit plan de sol en mosaïque comportant une pluralité de facettes, chacune desdites facettes ayant un pas et une pente respectifs, ledit plan de sol en mosaïque s'adaptant étroitement à un terrain de ladite image oblique affichée ; à connecter lesdits points de départ et final avec des segments de droite, lesdits segments de droite étant conformes auxdits pas et pente desdites facettes afin de suivre ainsi ledit terrain ; et à calculer la distance linéaire le long desdits segments de droite entre lesdits points de départ et final en tenant ainsi compte desdits pas et pente desdites facettes.

11. Système selon l'une des revendications 1 à 10, dans lequel ledit logiciel (140) d'affichage et d'analyse d'images superpose ledit plan de sol en mosaïque sur ladite image oblique affichée.

12. Système selon la revendication 10 ou 11, comprenant :

ledit dispositif d'entrée (134a, 134b) destiné à sélectionner un ou plusieurs points intermédiaires sur ladite image oblique affichée ; et
ledit logiciel (140) d'affichage et d'analyse d'images destiné à retrouver à partir dudit fichier de données les données de position correspondant au(x)dit(s) un ou plusieurs points intermédiaires ; à connecter les points intermédiaires adjacents l'un à l'autre, et à connecter lesdits points de départ et final aux points intermédiaires adjacents, au moyen de segments de droite, lesdits segments de droite étant conformes auxdits pas et pente desdites facettes, afin de suivre ainsi ledit terrain : et à calculer la distance le long desdits segments de droite entre lesdits points de départ et final.

13. Système selon l'une des revendications 1 à 12, dans lequel chacune des facettes ladite pluralité (162a, 162b, 162c, ...) correspond à des surfaces égales de ladite image oblique affichée.

14. Système selon l'une des revendications 1 à 13, dans lequel chacune des facettes de ladite pluralité (162a, 162b, 162c, ...) comprend un nombre égal de pixels de ladite image oblique affichée.

15. Système selon l'une des revendications 1 à 14, comprenant un dispositif d'entrée (134a, 134b) destiné à sélectionner un ou plusieurs points intermédiaires sur ladite image oblique affichée ; et ledit logiciel (140) d'affichage et d'analyse d'images destiné à retrouver les données de position correspondant auxdits points intermédiaires.

16. Système selon l'une des revendications 1 à 15, dans lequel ladite distance de séparation comprend une distance entre deux ou plus de deux points sélectionnés, une différence de hauteur entre deux ou plus de deux points sélectionnés, une différence en élévation entre deux ou plus de deux points sélectionnés, et une surface comprenant au moins trois points.

17. Système selon l'une des revendications 1 à 16, comprenant :

un dispositif de capture d'image (32a, 32b), ledit dispositif de capture d'image (32a, 32b) capturant des images obliques lors d'événements de capture d'image, ledit dispositif de capture d'image (32a, 32b) délivrant des signaux de données d'image correspondant aux images capturées;
au moins un dispositif de géolocalisation (34, ..., 44) délivrant au moins un signal de géolocalisation correspondant, chacun desdits au moins un signal de géolocalisation étant indicatif au moins en partie d'une géolocalisation dudit dispositif de capture d'image (32a, 32b) pendant chaque événement de capture d'image ; et
un système d'ordinateur (46) recevant et mémorisant lesdits signaux de données d'image et ledit au moins un signal de géolocalisation ; et
un logiciel (90) d'acquisition d'images lisant lesdits signaux d'image et ledit au moins un signal de géolocalisation, ledit logiciel (90) associant chaque signal de données d'image avec ledit au moins un signal de géolocalisation correspondant pour chaque événement de capture d'image.

18. Système selon la revendication 17, dans lequel ledit au moins un dispositif de géolocalisation et ledit au moins un signal de géolocalisation comprennent au moins :

soit une horloge (38) délivrant audit système d'ordinateur (46) de capture d'image des signaux de données de temps indicatifs d'un instant de chacun desdits événements de capture d'image ;
soit un récepteur de système de positionnement global (GPS) recevant des signaux GPS et délivrant audit système d'ordinateur (46) de capture d'image des signaux de données de loca-

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lisation indicatifs d'une longitude et d'une latitude dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ;
soit une unité (36) de navigation par inertie délivrant audit système d'ordinateur (46) de capture d'image des signaux de données de vitesse indicatifs d'une vitesse dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ;
soit un gyroscope (40) délivrant audit système d'ordinateur (46) de capture d'image un signal de tangage, un signal de roulis et un système de lacet respectivement indicatifs d'un tangage, d'un roulis et d'un lacet dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ;
soit un compas (42) délivrant audit système d'ordinateur (46) de capture d'image des signaux de données de cap indicatifs d'un cap dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image ; et
soit un altimètre (44) délivrant audit système d'ordinateur (46) de capture d'image des signaux de données d'altitude indicatifs d'une altitude dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image.

19. Dispositif selon la revendication 17 ou 18, comprenant en outre des données de correction indicatives des caractéristiques dudit dispositif (32a, 32b) de capture d'image comprenant la distance focale, la taille du capteur, la distorsion radiale, le décalage et l'alignement du point principal, ledit logiciel (90) d'acquisition d'images et de données utilisant lesdites données de correction pour corriger les images capturées.

20. Système selon l'une des revendications 17 à 19, comprenant en outre un fichier de données de sortie créé par logiciel (90) d'acquisition d'images et de données, ledit fichier de données de sortie comprenant une pluralité de fichiers d'images et de données de position correspondant à chacun des fichiers d'images de ladite pluralité.

21. Système selon l'une des revendications 17 à 20, comprenant en outre une plate-forme (20) portant ledit dispositif (32a, 32b) de capture d'image à une distance prédéterminée au-dessus d'une surface intéressante.

22. Système selon la revendication 21, dans lequel ledit dispositif (32a, 32b) de capture d'image capture des images obliques d'une zone intéressante en tant que dites images obliques en :

subdivisant la zone intéressante (200) en une pluralité de secteurs (202a, 202b, 202c) ;
guidant ladite plate-forme (20) selon un premier chemin (202) de manière à viser ainsi un ou plusieurs secteurs cibles avec ledit dispositif (32a, 32b) de capture d'image ;
capturant au moyen dudit dispositif (32a, 32b) de capture d'image une ou plusieurs images obliques de manière à couvrir ainsi une totalité de chacun desdits secteurs cibles dans les images obliques capturées à partir d'une première perspective ;
guidant ladite plate-forme (20) selon un deuxième chemin (204) de manière à viser ainsi lesdits secteurs cibles ;
capturant au moyen dudit dispositif (32a, 32b) de capture d'image une ou plusieurs images obliques de manière à couvrir ainsi une totalité de chacun desdits secteurs cibles dans les images obliques capturées à partir d'une deuxième perspective ;
répétant lesdites étapes de guidage et de capture selon des chemins sensiblement parallèles auxdits premier et deuxième chemins (202, 204) et espacés de ceux-ci, et capturant une ou plusieurs image(s) oblique(s) de manière à couvrir ainsi une totalité de chacun des secteurs cibles de ladite pluralité dans les images obliques capturées à partir de chacune desdites première et deuxième perspectives ; et
enregistrant les données de position indicatives d'une géolocalisation dudit dispositif (32a, 32b) de capture d'image à chaque événement de capture d'image.

23. Système selon la revendication 22, dans lequel ledit deuxième chemin (204) est sensiblement parallèle par rapport audit premier chemin (202) et à 180° (cent quatre-vingts degrés) de celui-ci.

24. Système selon la revendication 23, dans lequel ledit deuxième chemin (204) est également espacé dudit premier chemin (202).

25. Système selon l'une des revendications 22 à 24, dans lequel
ladite plate-forme (20) est guidée selon un troisième chemin (206) de manière à viser ainsi un ou plusieurs secteurs cibles au moyen dudit dispositif (32a, 32b) de capture d'image, ledit troisième chemin (206) étant sensiblement perpendiculaire auxdits premier et deuxième chemin (202, 204) ;
ledit dispositif (32a, 32b) de capture d'image capture une ou plusieurs image(s) oblique(s) de manière à couvrir ainsi une totalité de chacun desdits secteurs cibles dans les images obliques capturées à partir d'une troisième perspective ; dans lequel
ladite plate-forme (20) est guidée et ledit dispositif (32a, 32b) de capture d'image capture lesdites ima-

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ges obliques selon des chemins sensiblement parallèles audit troisième chemin (206) et espacés de celui-ci ; et
ledit dispositif (32a, 32b) de capture d'image capture une ou plusieurs image(s) oblique(s) de manière à couvrir ainsi une totalité de chacun des secteurs de ladite pluralité dans les images obliques capturées à partir de ladite troisième perspective.

26. Système selon la revendication 25, dans lequel ladite plate-forme (20) est guidée selon un quatrième chemin (208) de manière à viser un ou plusieurs sedeur(s) cible(s) avec ledit dispositif (32a, 32b) de capture d'image, ledit quatrième chemin (208) étant sensiblement parallèle audit troisième chemin (206) et à 180° (cent quatre-vingts degrés) dudit troisième chemin ;
ledit dispositif (32a, 32b) de capture d'image capture une ou plusieurs image(s) oblique(s) de manière à couvrir ainsi une totalité de chacun desdits secteurs cibles dans les images obliques capturées à partir d'une quatrième perspective ; et
lesdites étapes de guidage et de capture sont répétées selon des chemins sensiblement parallèles audit quatrième chemin (208) et espacés de celui-ci et capturant une ou plusieurs image(s) oblique(s) de manière à couvrir ainsi une totalité de chacun des secteurs cibles de ladite pluralité dans les images obliques capturées à partir de ladite quatrième perspective.

27. Système selon la revendication 26, dans lequel ledit quatrième chemin (208) est également espacé dudit troisième chemin (206).

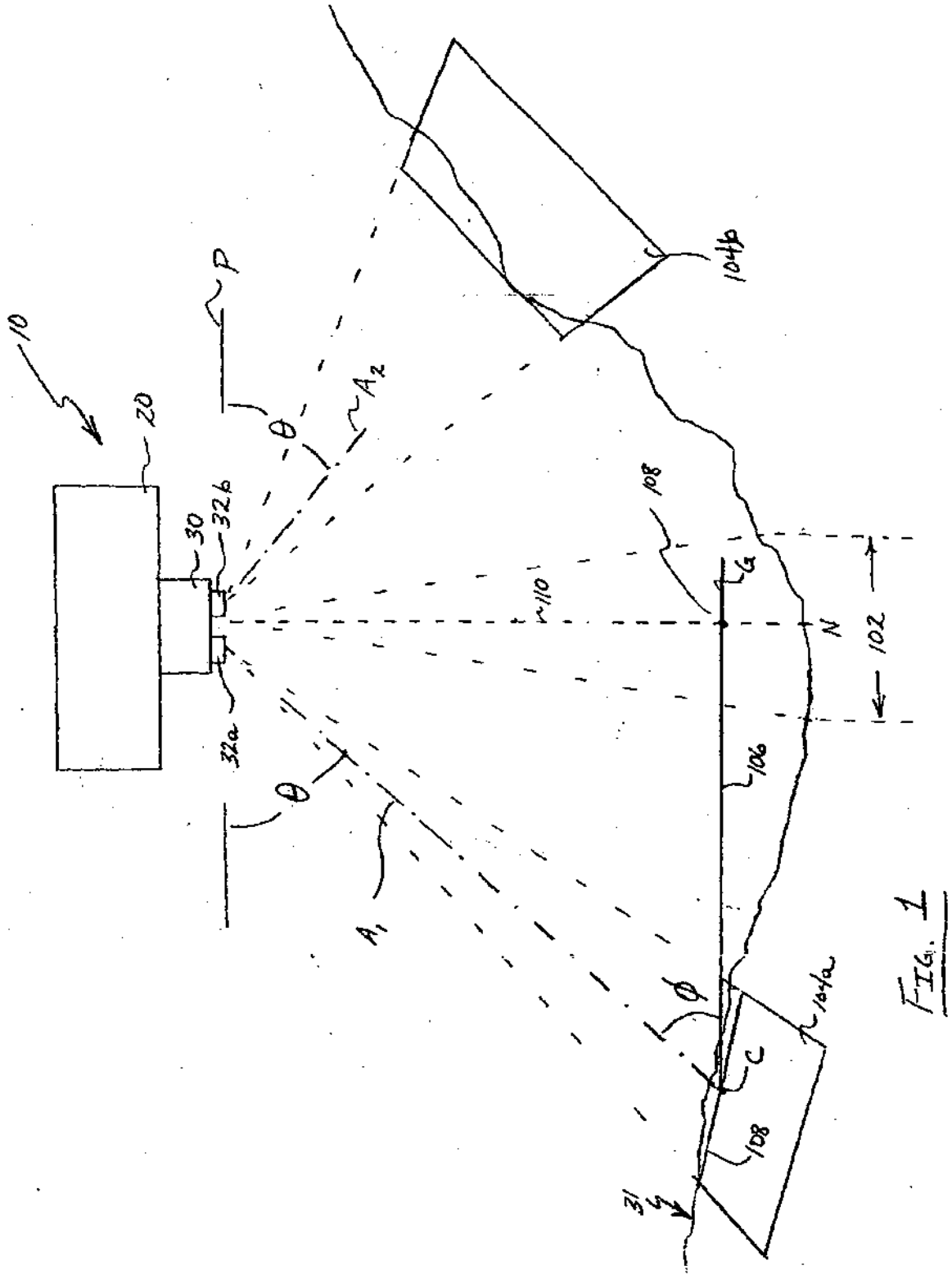


FIG. 1

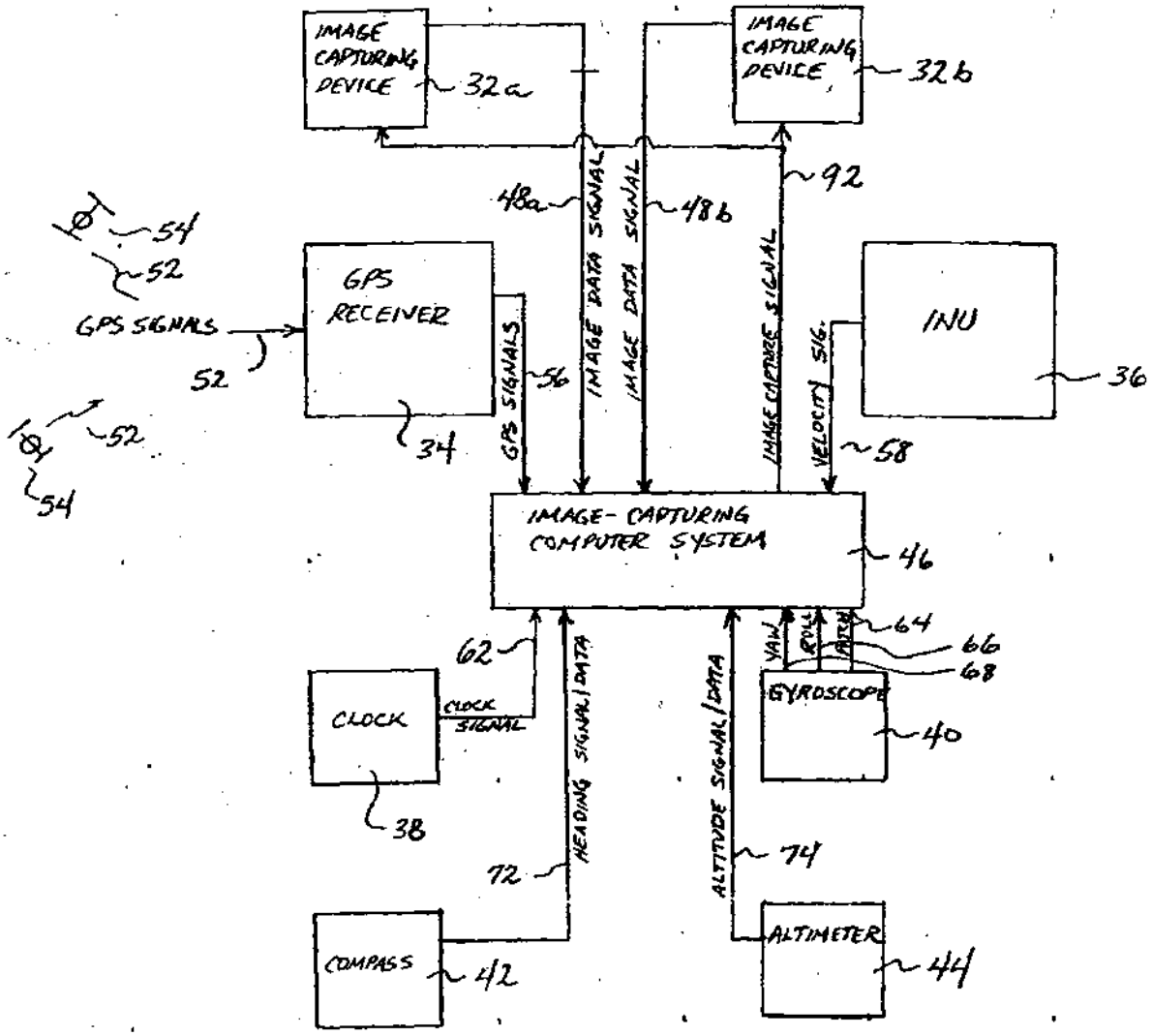

IMAGE CAPTURING DEVICE
32a
IMAGE CAPTURING DEVICE
32b
92
48a
48b
IMAGE DATA SIGNAL
IMAGE DATA SIGNAL
IMAGE CAPTURE SIGNAL
54
52
GPS SIGNALS
52
GPS RECEIVER
34
GPS SIGNALS
56
INU
36
VELOCITY SIG.
58
52
54
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
CLOCK
CLOCK SIGNAL
38
HEADING SIGNAL/DATA
72
ALTITUDE SIGNAL/DATA
74
YAW
ROLL
PITCH
64
66
68
GYROSCOPE
40
COMPASS
42
ALTIMETER
44

FIG. 2

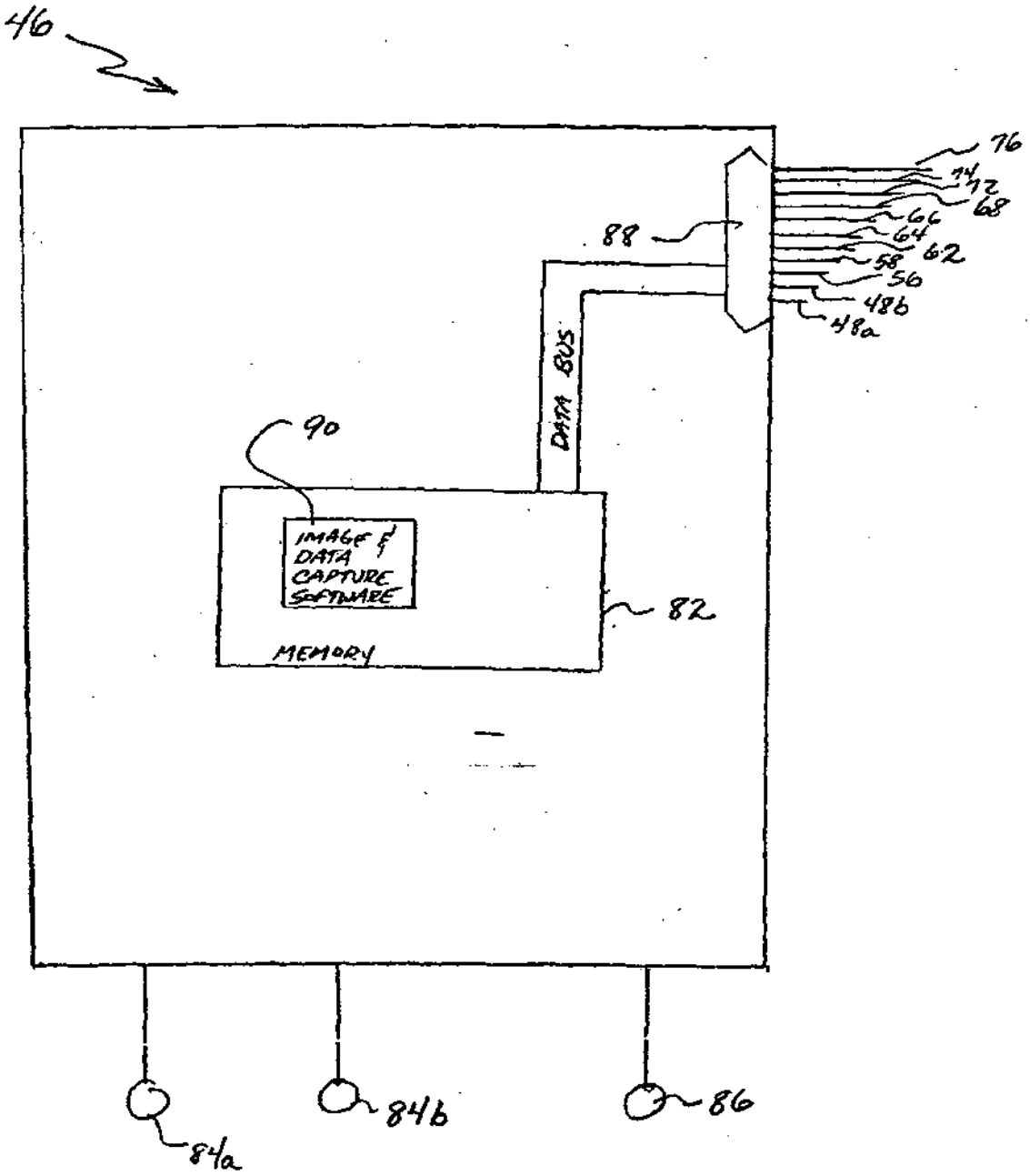

46
76
74
72
68
66
64
62
58
56
48b
48a
88
DATA BUS
90
IMAGE & DATA CAPTURE SOFTWARE
MEMORY
82
84a
84b
86

FIG. 3

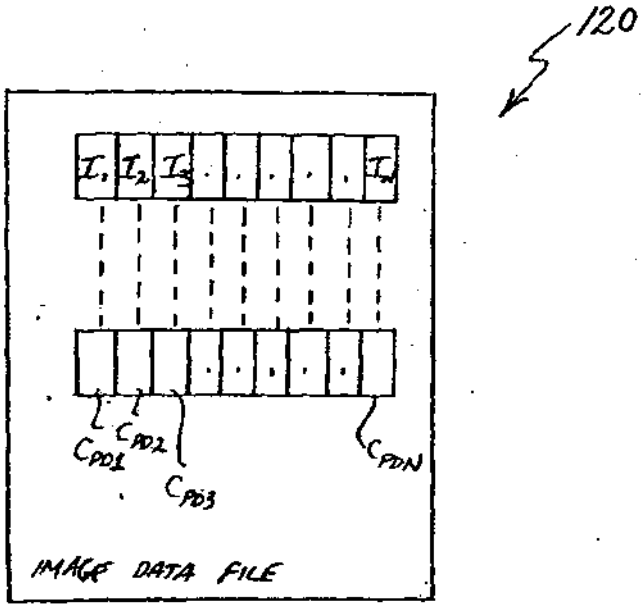


FIG. 4

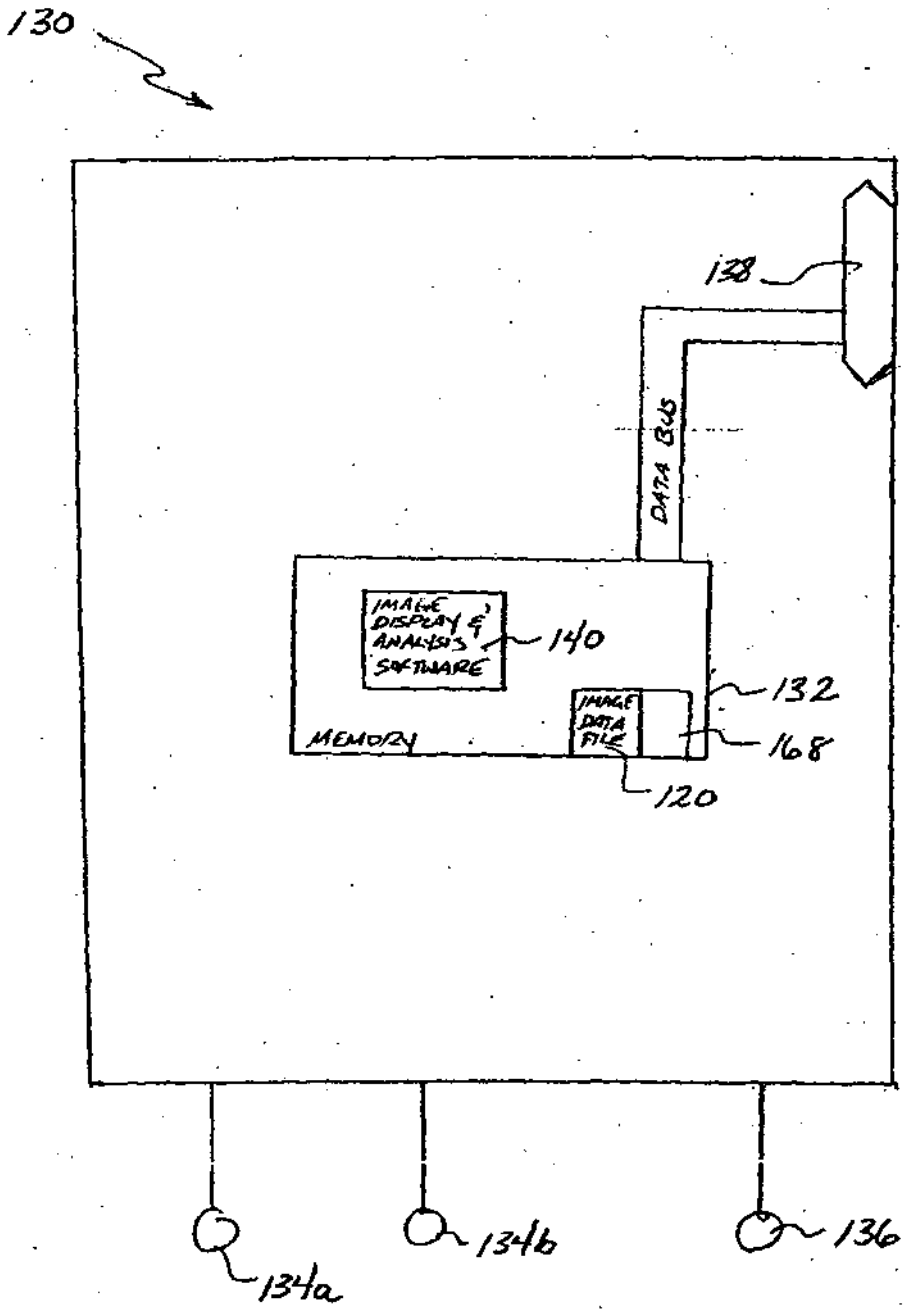

130
138
DATA BUS
IMAGE DISPLAY & ANALYSIS SOFTWARE
140
132
IMAGE DATA FILE
168
MEMORY
120
134a
134b
136

FIG. 5

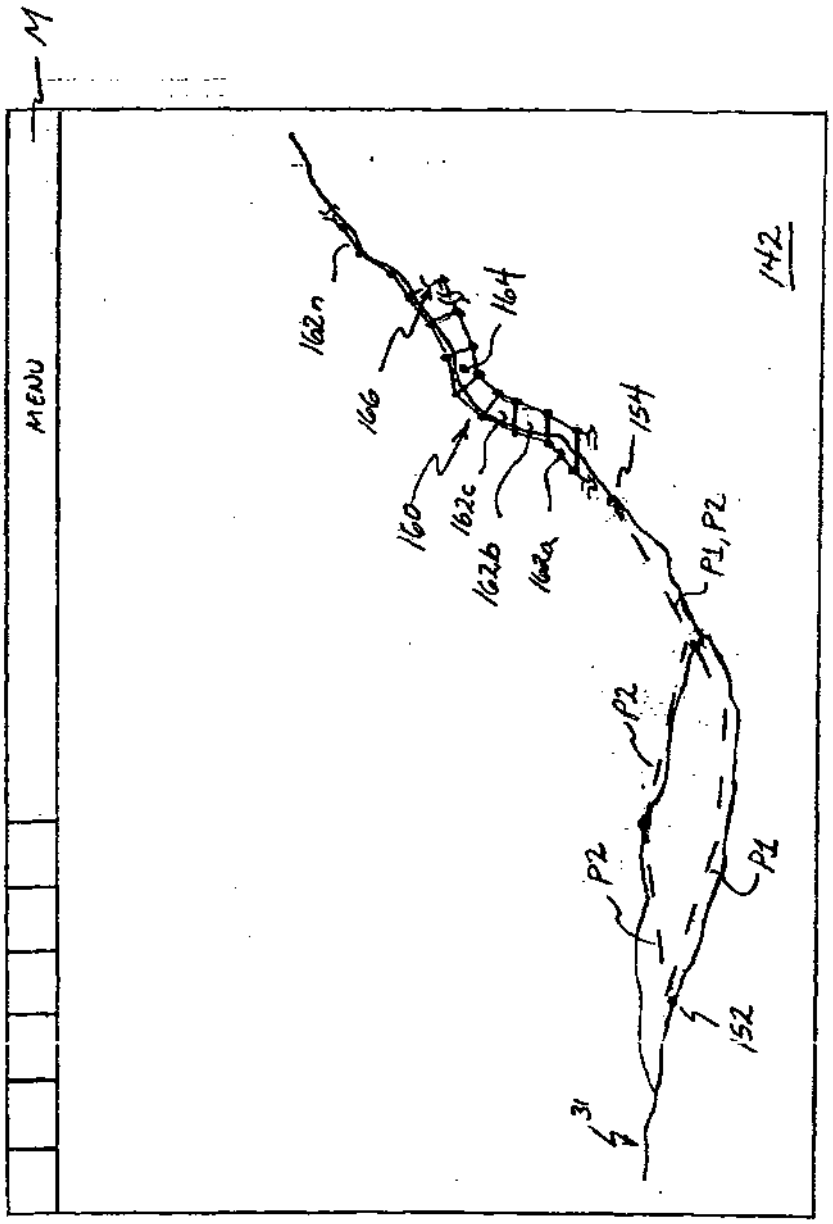

M
MENU
142
162n
164
166
154
160
162c
162b
162a
P1, P2
P2
P2
P1
152
31

FIG. 6

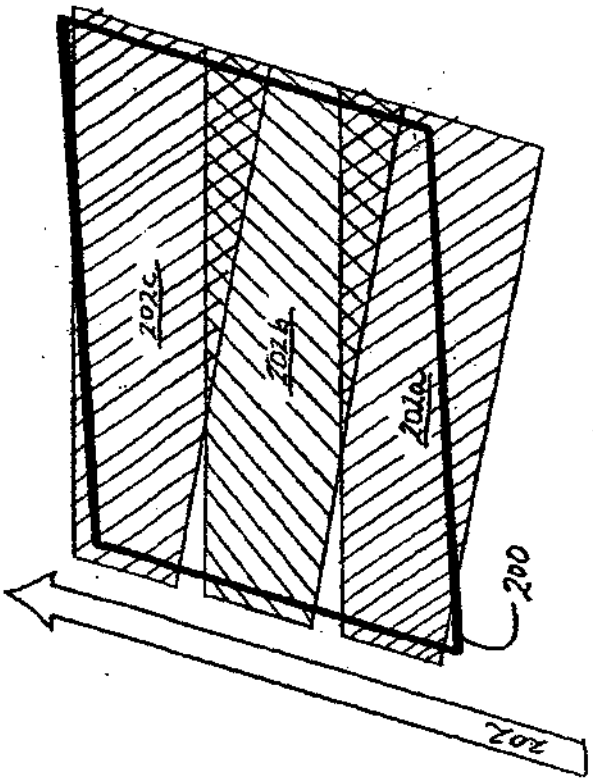


Fig. 1

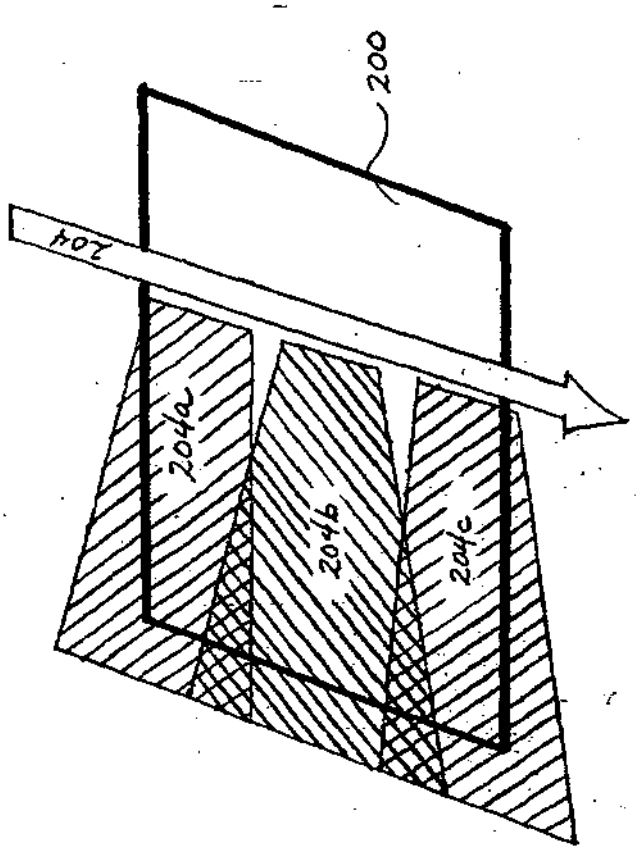


FIG. 8

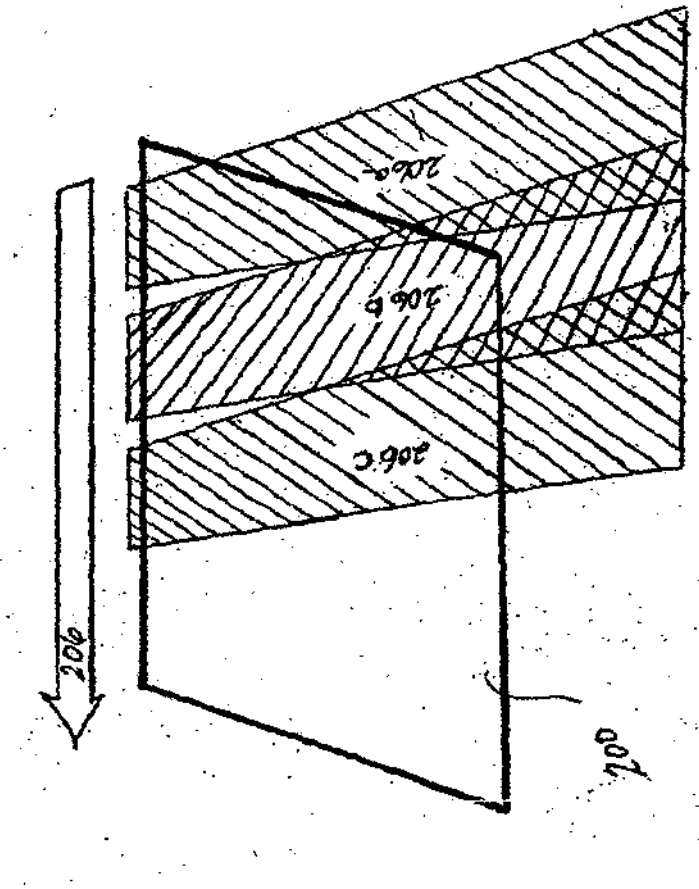


Fig. 9

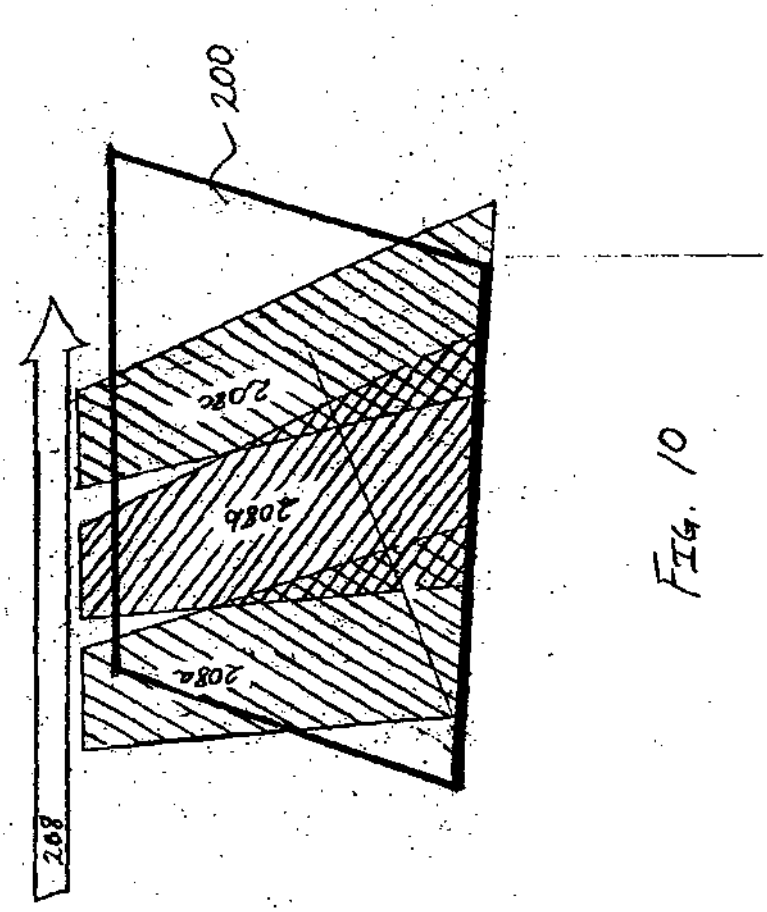


FIG. 10

[19] 中华人民共和国国家知识产权局

[51] Int. Cl.
G06K 9/40 (2006.01)

[12] 发明专利申请公开说明书

[21] 申请号 200380108517.2

[43] 公开日 2006 年 2 月 15 日

[11] 公开号 CN 1735897A

[22] 申请日 2003.11.7
[21] 申请号 200380108517.2
[30] 优先权
[32] 2002.11.8 [33] US [31] 60/425,275
[86] 国际申请 PCT/US2003/035528 2003.11.7
[87] 国际公布 WO2004/044692 英 2004.5.27
[85] 进入国家阶段日期 2005.7.8
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[74] 专利代理机构 永新专利商标代理有限公司
代理人 王 英

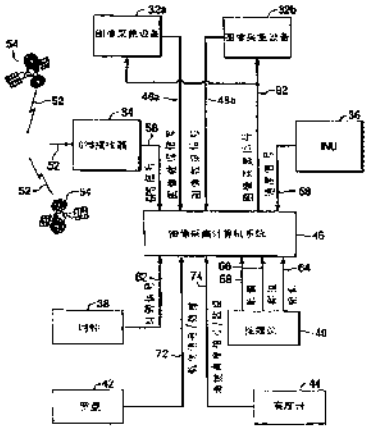
权利要求书 9 页 说明书 20 页 附图 7 页

[54] 发明名称

倾斜地理定位和测量系统

[57] 摘要

一种从采集的倾斜图像(32a 和 32b)进行显示，地理定位和测量的计算机化系统(46)包括可由计算机系统访问的数据文件。数据文件包括与多个采集的倾斜图像(32a 和 32b)对应的多个图像文件，和与该图像对应的位置数据。图像显示和分析软件由系统(46)执行，以读取数据文件以及显示采集的倾斜图像的至少一部分。该软件检索用户在显示图像上选择的一个或多个点的位置数据，并且计算任何两个或多个选择点之间的分离距离。该分离距离计算是用户可选择的，以确定各种参数，包括选择点之间的直线距离，由选择点包围的面积，选择点的相对标高，和选择点之间的高度差。



1．一种用于采集图像及相应的地理位置数据的系统，包括：

图像采集设备，所述图像采集设备在图像采集事件中采集倾斜图像，所述图像采集设备发出与所采集图像对应的图像数据信号；

至少一个地理定位设备，所述至少一个地理定位设备中的每一个发出相应的至少一个地理定位信号，所述至少一个地理定位信号的每一个在每个图像采集事件期间至少表示部分所述图像采集设备的地理位置；以及

计算机系统，其接收和存储所述图像数据信号和所述至少一个地理定位信号；以及

图像和数据获取软件，其读取所述图像数据信号和所述至少一个地理定位信号，对于每个图像采集事件，所述软件将每个所述图像数据信号与相应的所述至少一个地理定位信号相关联。

2．根据权利要求1所述的系统，其中所述至少一个地理定位设备和所述至少一个地理定位信号分别包括以下至少之一：

向所述图像采集计算机系统发出时间数据信号的时钟，所述时间数据信号表示每个所述图像采集事件的时间；

全球定位系统(GPS)接收器，其接收GPS信号，并在每个所述图像采集事件中，将表示所述图像采集设备经度和纬度的位置数据信号发送到所述图像采集计算机系统；

惯性导航设备(INU)，其在每个所述图像采集事件中，将表示所述图像采集设备速度的速度数据信号发送到所述图像采集计算机系统；

陀螺仪，其在每个所述图像采集事件中，将分别表示所述图像采集设备的俯仰、滚动和偏航的俯仰信号、滚动信号和偏航信号，发送到所述图像采集计算机系统；

罗盘，其在每个所述图像采集事件中，将表示所述图像采集设备

航向的航向数据信号发送到所述图像采集计算机系统；以及

高度计，其在每个所述图像采集事件中，将表示所述图像采集设备海拔高度的海拔高度数据信号发送到所述图像采集计算机系统。

3．根据权利要求 1 所述的系统，其中所述至少一个地理定位设备和所述至少一个地理定位信号分别包括：

向所述图像采集计算机系统发出时间数据信号的时钟，所述时间数据信号表示每个所述图像采集事件的时间；

全球定位系统(GPS)接收器，其接收 GPS 信号，并在每个所述图像采集事件中，将表示所述图像采集设备经度和纬度的位置数据信号发送到所述图像采集计算机系统；

惯性导航设备(INU)，其在每个所述图像采集事件中，将表示所述图像采集设备速度的速度数据信号发送到所述图像采集计算机系统；

陀螺仪，其在每个所述图像采集事件中，将分别表示所述图像采集设备的俯仰、滚动和偏航的俯仰信号、滚动信号和偏航信号发送到所述图像采集计算机系统；

罗盘，其在每个所述图像采集事件中，将表示所述图像采集设备航向的航向数据信号发送到所述图像采集计算机系统；以及

高度计，其在每个所述图像采集事件中，将表示所述图像采集设备海拔高度的海拔高度数据信号发送到所述图像采集计算机系统。

4．根据权利要求 1 所述的系统，进一步包括表示所述图像采集设备特性的校正数据，所述特性包括焦距、传感器尺寸、径向畸变、主点偏移和对准，所述图像和数据获取软件利用所述校正数据来校正采集的图像。

5．根据权利要求 1 所述的系统，进一步包括由所述图像和数据获

取软件产生的输出数据文件，所述输出数据文件包括多个图像文件和与所述多个图像文件中的每一个对应的位置数据。

6．根据权利要求 1 所述的系统，进一步包括一个平台，该平台将所述图像采集设备携带到距感兴趣表面上方预定的距离。

7．一种计算机化系统，基于采集的倾斜图像用于显示、地理定位和进行测量，包括：

具有存储器的计算机系统；

图像和数据文件，其可由所述系统进行访问，并且包括与多个采集的倾斜图像对应的多个图像文件，所述图像和数据文件进一步包括与所述多个图像文件对应的位置数据；

图像显示和分析软件，其由所述系统运行，以读取所述图像和数据文件，并将该采集的倾斜图像的至少一部分作为显示图像进行显示，所述软件检索所述显示图像中的一个或多个选择点的所述位置数据，所述软件计算所述显示图像中的任何两个或多个选择点之间的分离距离。

8．根据权利要求 7 所述的系统，进一步包括表示方块状地平面的地平面数据文件，所述地平面数据文件可由所述计算机系统访问，所述地平面数据文件表示与所述采集的倾斜图像中描述的地形的至少一部分十分近似的方块状地平面。

9．根据权利要求 8 所述的系统，其中所述方块状地平面进一步包括多个互连的小平面，所述多个小平面中的每一个具有各自的间距和坡度。

10. 根据权利要求 9 所述的系统，其中所述地平面数据文件包括多个顶点，所述多个顶点中的每一个具有各自的标高，并且定义所述多个互连小平面的角，所述多个顶点中的两个由所述互连小平面中的每一个共有。

11. 根据权利要求 10 所述的系统，其中所述图像显示和分析软件识别所述多个小平面中的哪一个对应于所述显示图像上的选择点，并且计算所述选择点的标高，所述标高至少部分取决于与该选择点对应的该小平面的顶点的标高，所述图像显示和分析软件使用所述计算的标高计算所述选择点和一个或多个其它选择点之间的所述分离距离。

12. 根据权利要求 11 所述的系统，其中所述图像显示和分析软件通过计算两个或多个选择点之间的该分离距离，来计算所述显示图像中物体的高度。

13. 根据权利要求 8 所述的系统，其中所述方块状地平面为叠加和拟合到所述显示图像上的一个。

14. 根据权利要求 7 所述的系统，其中所述图像显示和分析软件包括用户可选择的测量模式，可以通过下拉菜单、工具栏和键盘命令中的至少一种访问该模式。

15. 根据权利要求 7 所述的系统，其中所述图像中的每一个由图像采集设备在各个图像采集事件中采集，所述图像和数据文件的所述位置数据包括：

表示每个图像采集事件时间的时间数据；

在每个图像采集事件中表示该图像采集设备位置的位置数据；

在每个图像采集事件中表示该图像采集设备定向的定向数据；

表示该图像采集设备的校正系数的校正数据；以及

表示由该图像采集设备所采集的该表面的平均标高的标高数据。

16．根据权利要求 15 所述的系统，其中所述位置数据包括在每个图像采集事件中所述图像采集设备的纬度、经度和海拔高度。

17．根据权利要求 15 所述的系统，其中所述定向数据包括在每个图像采集事件中所述图像采集设备的滚动、俯仰、偏航和航向。

18．根据权利要求 15 所述的数据组，其中所述图像采集设备是照相机，且所述校正数据至少包括焦距、传感器尺寸、长宽比、主点偏移、畸变和像素间距中的一个。

19．用于在显示的倾斜图像中进行测量的计算机化方法，包括：

在该显示图像上用输入设备选择起始点和结束点；

从数据文件检索与所述起始点和所述结束点对应的位置数据；

参考与具有多个小平面的方块状地平面对应的地平面数据文件，所述小平面中的每一个具有各自的间距和坡度，所述方块状地平面与所述显示的倾斜图像的地形精密地匹配；

用线段将所述起始点和结束点连接，所述线段符合所述小平面的所述间距和坡度，由此遵循所述地形；以及

沿所述起始点和结束点之间的所述线段计算该线距离，因此，考虑到了所述小平面的所述间距和坡度。

20．根据权利要求 19 所述的方法，其中所述方块状地平面叠加在所述显示的倾斜图像上。

21．根据权利要求 19 所述的方法，进一步包括以下步骤：

在该显示图像上用输入设备选择一个或多个中间点；

从所述数据文件检索与所述一个或多个中间点对应的位置数据；以及

将相邻的中间点彼此连接，并且用线段将所述起始点和结束点连接到相邻的中间点，所述线段符合所述小平面的所述间距和坡度，由此遵循所述地形；以及

沿所述起始点和结束点之间的所述线段计算该距离。

22．根据权利要求 19 所述的方法，其中所述多个小平面中的每一个与所述显示的倾斜图像的相等面积相对应。

23．根据权利要求 19 所述的方法，其中所述多个小平面中的每一个包括所述显示的倾斜图像的相等数量的像素。

24．一种计算机化方法，用于从显示在计算机系统上的倾斜图像上进行测量，至少一个输入设备连接到所述计算机系统，图像数据文件可由所述计算机系统访问，所述图像数据文件包括与之对应的采集的图像和位置数据，所述计算机化方法包括：

将该计算机系统置于多个测量模式的所需一个之中，配置该所需的测量模式，以计算所需的测量；

在该显示图像上选择起始点；

检索与所述起始点对应的该位置数据；

在该显示图像上选择结束点；

检索与所述结束点对应的该位置数据；以及

计算该所需的测量，该测量至少部分地取决于所述起始点和结束

点的所述位置数据。

25. 根据权利要求 24 所述的方法，进一步包括以下步骤：

在所述显示图像上选择一个或多个中间点；以及

检索与所述中间点对应的该位置数据。

26. 根据权利要求 24 所述的方法，其中所述多个测量模式包括：距离测量模式，用于计算两个或多个选择点之间的距离；高度测量模式，用于计算两个或多个选择点之间的高度差；相对标高测量模式，用于计算两个或多个选择点标高的差值；和面积测量模式，用于计算由至少三个点包围的面积。

27. 用平台携带的图像采集设备来采集感兴趣区域的倾斜图像的一种方法，在各个图像采集事件中采集每个倾斜图像，所述方法包括：

将该感兴趣区域分为多个区；

沿第一路线引导该平台，由此用该图像采集设备瞄准一个或多个目标区；

用该图像采集设备采集一个或多个倾斜图像，由此在从第一视角采集的倾斜图像中覆盖每个所述目标区的全部；

沿第二路线引导该平台，由此瞄准所述目标区；

用该图像采集设备采集一个或多个倾斜图像，由此在从第二视角采集的倾斜图像中覆盖每个所述目标区的全部；

沿着基本上与所述第一和第二路线平行且与所述第一和第二路线间隔一定距离的路线，重复所述引导和采集步骤，并且采集一个或多个倾斜图像，由此，在从所述第一和第二视角中的每一个采集的倾斜图像中，覆盖了所述多个区中每一个的全部；以及

在每个图像采集事件中，记录表示所述图像采集设备地理位置的

位置数据。

28. 根据权利要求 27 所述的方法，其中所述第二路线基本上平行于所述第一路线，且关于所述第一路线成 180°(180 度)。

29. 根据权利要求 28 所述的方法，其中所述第二路线也与所述第一路线间隔一定距离。

30. 根据权利要求 27 所述的方法，进一步包括以下步骤：

沿第三路线引导该平台，由此用该图像采集设备瞄准一个或多个目标区，所述第三路线基本上与所述第一和第二路线垂直；

用该图像采集设备采集一个或多个倾斜图像，由此在从第三视角采集的倾斜图像中采集每个所述目标区的全部；以及

沿着基本上与所述第三路线平行而且与所述第三路线间隔一定距离的路线，重复所述引导和采集步骤，并且采集一个或多个倾斜图像，由此在从所述第三视角采集的倾斜图像中覆盖所述多个区中每一个的全部。

31. 根据权利要求 30 所述的方法，进一步包括以下步骤：

沿第四路线引导该平台，由此用该图像采集设备瞄准一个或多个目标区，所述第四路线基本上平行于所述第三路线，并且与所述第三路线成 180°(180 度)角；

用该图像采集设备采集一个或多个倾斜图像，由此在从第四视角采集的倾斜图像中采集每个所述目标区的全部；以及

沿基本上与所述第四路线平行而且与所述第四路线间隔一定距离的路线重复所述引导和采集步骤，并且采集一个或多个倾斜图像，由此在从所述第四视角采集的倾斜图像中覆盖所述多个区中每一个的

全部。

32. 根据权利要求 31 所述的方法，其中所述第四路线也与所述第三路线间隔一定距离。

倾斜地理定位和测量系统

相关申请的相互引用

本申请要求申请日为 2002 年 11 月 8 日、序列号为 60/425275 的美国临时专利申请的权益。

发明领域

本发明涉及摄影测量，尤其涉及用于采集倾斜图像和用于测量物体以及图像中所示物体之间的距离的方法和装置。

技术背景

摄影测量是对显示在照片中、尤其是航摄照片中的物体及物体之间进行测量的一门科学。通常，摄影测量包括拍摄地形特征的图像，并且从其推导数据，例如，该数据表示所述图像中物体之间的相对距离及物体的尺寸。摄影测量也可以包括将照片与其它数据联系起来，例如代表纬度和经度的数据。实际上，所述图像被叠加并且符合特定的空间坐标系。

传统的摄影测量包括采集和/或获取正交图像。诸如照相机或传感器这样的图像采集设备是正交图像。诸如照相机或传感器这样的图像采集设备由诸如飞机或卫星这样的运载体或平台携带，并且瞄准平台正下方的和/或从平台垂直向下的最底点(nadir point)。图像中对应于最底点的点或像素是精确地与图像采集设备正交的唯一的点/像素。图像中所有其它的点或像素实际上相对于图像采集设备倾斜。当点或像素逐渐远离最底点时，它们相对于图像采集设备愈加地倾斜，并且地面取样距离(即，对应于每个像素或由每个像素覆盖的表面积)也增加。正交图像中的倾斜导致图像中的特征畸变，尤其在离最底点较远

的图像中。

该畸变通过正交校正过程被消除或补偿，实质上，通过在正网格(orthometric grid)或坐标系上拟合或弯曲正交图像的每个像素，所述正交校正过程从正交图像中消除倾斜。所述正交校正过程产生了图像，其中所有的像素具有相同的地面取样距离并且都被朝北定向。因此，在正交校正图像上的任何点都可以使用 X，Y 坐标系来定位，并且只要知道图像比例，就能够计算出地形特征的长度和宽度，以及这些特征之间的相对距离。

尽管正交校正过程一定程度上补偿了正交图像中的倾斜畸变，但是它在正交校正的正交图像中引入了其它不期望的畸变和/或误差。由于多数观察者不习惯从上方观察物体，尤其是地形特征，因此显示在正交校正过的正交图像中的物体可能难以识别和/或鉴定。对于未受培训的观察者而言正交校正图像具有许多畸变。实际上直的道路看上去弯曲，建筑物可能看上去倾斜。而且，正交校正图像基本上不包含关于地形特征的高度信息。为了识别这种图像中的物体和地形特征，正交和/或正交校正正交图像的解释和分析通常由受过高等培训的分析员来进行，这些人员接受了多年的专门培训并且具有多年的经验。

因此，尽管正交和正交校正图像在摄影测量中有用，但是它们缺少关于其中所示特征的高度信息，并且要求受过高等培训的分析员来解释图像所显示的细节。

倾斜图像是用通常瞄准或指向携带图像采集设备的平台的侧向或下方的图像采集设备采集的图像。与正交图像不同，倾斜图像显示了诸如房屋、建筑和/或山脉这样的地形特征的侧部及其顶部。因此，观察倾斜图像比观察正交或正交校正图像更自然和直观，甚至临时的观察者也能够识别和解释显示在倾斜图像中的地形特征和其它物体。在倾斜图像的前景中的每个像素对应于所示的表面或物体的较小面

积(即，每个前景像素具有较小的地面取样距离)，而背景中的每个像素对应于所示的表面或物体的较大面积(即，每个背景像素具有较大的地面取样距离)。倾斜图像采集对象表面或物体的大致梯形面积或视图，并且梯形前景具有基本上比梯形背景小的地面取样距离(即，更高的分辨率)。

在摄影测量中倾斜图像被认为几乎或完全没有用处。将不同尺寸的倾斜图像的前景像素和背景像素变换为统一的尺寸，并由此在坐标系上弯曲该图像的传统方法极大地扭曲了倾斜图像，并且由此造成了物体的识别以及在图像中显示物体的测量任务变得费力而不精确。通过使用高程模型在倾斜图像中进行地形移位的校正进一步扭曲了图像，由此增加了进行测量的难度，而减小了任何这样的测量的精确度。

因此，尽管在摄影测量中倾斜图像被认为几乎或完全没有用处，但是它们容易被理解，并且包含关于其中所示特征的高度信息。

因此，在本领域中需要一种用于摄影测量的方法和装置，其能够实现倾斜图像中的地理定位和精确测量。

而且，在本领域中需要一种用于摄影测量的方法和装置，其能够实现图像中物体的标高和相对标高的测量。

进一步地，在本领域中需要一种用于摄影测量的方法和装置，其利用更多直观的和自然的图像。

发明内容

本发明提供了用于采集、显示和测量物体以及倾斜图像中所示的物体之间的距离的一种方法和装置。

本发明的一种形式包括从采集的倾斜图像进行显示、地理定位和测量的计算机化系统。该系统包括可由计算机系统访问的数据文件。数据文件包括对应于多个采集的倾斜图像的多个图像文件，和对应于该图像的位置数据。该系统运行图像显示和分析软件，以读取数据文件以及显示所述采集的倾斜图像的至少一部分。该软件为显示图像上

的一个或多个用户选择点检索位置数据，并且计算任何两个或多个选择点之间的分离距离。该分离距离计算是用户可选择的，其用于确定各种参数，包括选择点之间的直线距离，选择点内包围的面积，选择点的相对标高，选择点之间的高度差。

附图简述

当结合附图阅读时，参考本发明的实施例的以下描述，本发明的上述和其它特征和优点以及实现它们的方式将变得明显并被完全理解，其中：

图 1 示出了携带本发明的图像采集系统的平台或运载体的一个实施例，并且示出了由此拍摄的典型正交图像和倾斜图像；

图 2 是图 1 的图像采集系统的简图；

图 3 是图 2 的图像采集计算机系统的结构图；

图 4 是图 1 的图像采集系统的示例性输出数据文件的图示；

图 5 是本发明的图像显示和测量计算机系统的一个实施例的结构图，所述系统用于显示并对在由图 1 的图像采集系统采集的图像中所示的物体及物体之间进行测量；

图 6 示出了显示在图 5 的系统上的示例性图像，并且示出了对在该图像中所示物体及物体之间进行测量的本发明的方法的一个实施例；

图 7 和 8 示出了本发明用于采集倾斜图像的方法的一个实施例；

图 9 和 10 示出了本发明用于采集倾斜图像的方法的第二实施例；

在所有的这几幅图中相应的附图标记表示相应的部分。这里阐述的范例以一种形式说明了本发明的优选实施例，并且该范例不旨在以任何方式限制本发明的范围。

发明详述

现在参考附图，尤其参考图 1，示出了本发明用于对倾斜图像进

行采集和地理定位的装置的一个实施例。装置 10 包括携带图像采集和地理定位系统 30 的平台或运载体 20。

平台 20，例如飞机，航天飞机，火箭，卫星，或者任何合适的运载体，在表面 31 的预定区域上方和在表面 31 上的一个或多个预定海拔高度携带图像采集系统 30，所述表面 31 例如为地球表面或者任何感兴趣的其它表面。因而，平台 20 能够在有人驾驶或无人驾驶情况下，经由例如地球大气层或外层空间沿着预定的飞行路径或路线受控运动或者飞行。图像采集平台 20 包括用于产生和调节能量的系统(未示出)，该系统例如包括一个或多个发动机，燃料电池，太阳电池板，和/或电池，为图像采集系统 30 提供动力。

从图 2 中最清楚地看到，图像采集和地理定位系统 30 包括图像采集设备 32a 和 32b，全球定位系统(GPS)接收器 34，惯性导航单元(INU)36，时钟 38，陀螺仪 40，罗盘 42 和高度计 44，它们中的每一个都与图像采集计算机系统 46 互连。

图像采集设备 32a 和 32b，例如传统相机，数字相机，数字传感器，电荷耦合器件，或者其它合适的图像采集设备，能够用摄像或者电子仪器采集图像。图像采集设备 32a 和 32b 所具有的已知或确定的特性包括焦距，传感器尺寸和长宽比，径向畸变和其它畸变项，主点偏移，像素间距，和对准。图像采集设备 32a 和 32b 分别获取图像和发出图像数据信号(IDS)48a 和 48b，该图像信号对应于拍摄的特定图像或照片并且存储在图像采集计算机系统 46 中，以下更具体地描述。

如图 1 所示，图像采集设备 32a 和 32b 各自具有中心轴 A_1 和 A_2，并且安装到平台 20 上，使得每一个轴 A_1 和 A_2 相对于水平面 P 具有偏角 θ。偏角 θ 实质上是任何倾斜角度，但是优选地从大约 20°(20 度)到大约 60°(60 度)，并且最优选地从大约 40°(40 度)到大约 50°(50 度)。

GPS 接收器 34 接收全球定位系统信号 52，该信号由一个或多个全球定位系统卫星 54 发射。GPS 信号 52 以公知的形式能够确定平台

20 相对于表面 31 的精确位置。GPS 接收器 34 对 GPS 信号 52 进行译码并且发出位置信号/数据 56，该位置信号/数据 56 至少部分地取决于 GPS 信号 52，并指示了平台 20 相对于表面 31 的精确位置。对应于图像采集设备 32a 和 32b 采集的每个图像的位置信号/数据 56 被图像采集计算机系统 46 接收和存储。

INU 36 是传统的惯性导航单元，其连接到图像采集设备 32a 和 32b 和/或平台 20，并且检测图像采集设备 32a 和 32b 和/或平台 20 的速度的变化，包括平动速度和旋转速度。INU 36 将表示速度和/或速度变化的速度信号/数据 58 发送到存储速度信号/数据 58 的图像采集计算机系统 46，该速度信号/数据 58 对应于由图像采集设备 32a 和 32b 采集并且被图像采集计算机系统 46 接收和存储的每个图像。

时钟 38 保持准确的时间测量值(有效时间)，该时间测量值用于对图像采集和地理定位系统 30 中的事件进行同步。时钟 38 提供了时间数据/时钟信号 62，所述时间数据/时钟信号 62 表示图像采集设备 32a 和 32b 拍摄图像的准确时间。时间数据 62 也被提供给图像采集计算机系统 46 并由图像采集计算机系统 46 存储。可选地，时钟 38 与图像采集计算机系统 46 集成在一起，例如时钟软件程序。

陀螺仪 40 是在飞机上和/或用于飞机的商业导航系统中很常见的传统的陀螺仪。陀螺仪 40 提供的信号包括俯仰信号 64，滚动信号 66 和偏航信号 68，其分别表示平台 20 的俯仰，滚动和偏航。对应于图像采集设备 32a 和 32b 采集的每个图像的俯仰信号 64，滚动信号 66 和偏航信号 68 被图像采集计算机系统 46 接收和存储。

罗盘 42，例如传统的电子罗盘，指示平台 20 的航向。罗盘 42 发出表示平台 20 航向的航向信号/数据 72。图像采集计算机系统 46 接收和存储该航向信号/数据 72，该航向信号/数据 72 对应于图像采集设备 32a 和 32b 采集的每个图像。

高度计 44 指示平台 20 的海拔高度。高度计 44 发出海拔高度信号

/数据 74，图像采集计算机系统 46 接收和存储该海拔高度信号/数据 74，该海拔高度信号/数据 74 对应于图像采集设备 32a 和 32b 采集的每个图像。

如图 3 所示，图像采集计算机系统 46，例如传统的膝上型个人电脑，包括存储器 82，输入设备 84a 和 84b，显示设备 86，和输入和输出(I/O)端口 88。图像采集计算机系统 46 运行图像和数据获取软件 90，该软件存储在存储器 82 中。图像采集计算机系统 46 在其操作期间使用和/或计算的数据也存储在存储器 82 中，并且存储器 82 包括，例如非易失性只读存储器，随机存取存储器，硬盘存储器，移动存储卡和/或其它合适的记忆体存储设备和/或介质。输入设备 84a 和 84b，例如鼠标，键盘，控制杆等，使得能够进行数据的输入，以及用户和由图像采集计算机系统 46 运行的软件之间的交互作用。显示设备 86，例如液晶显示器或阴极射线管，向图像采集计算机系统 46 的用户显示信息。I/O 端口 88，例如串行和并行数据输入和输出端口，使得能够向图像采集计算机系统 46 输入和/或从其输出数据。

上述的每一个数据信号都连接到图像采集计算机系统 46。更具体地，图像数据信号 48，位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66 和 68，航向信号 72 和海拔高度信号 74 通过 I/O 端口 88 被接收并且存储在图像采集计算机系统 46 的存储器 82 中。

在使用时，图像采集计算机系统 46 运行图像和数据获取软件 90，该软件通常控制对上述数据信号的读取、操作和存储。更具体地，图像和数据获取软件 90 读取图像数据信号 48a 和 48b，并将它们存储在存储器 82 中。表示在获取图像瞬间的存在状态的位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66 和 68，航向信号 72 和海拔高度信号 74 中的每一个由图像采集设备 32a 和 32b 获取和采集，并且对应于表示所采集的图像的特定图像数据信号

48a 和 48b，这些信号通过 I/O 端口 88 由图像采集计算机系统 46 接收。运行图像和数据获取软件 90 的图像采集计算机系统 46 将图像采集信号 92 发送到图像采集设备 32a 和 32b，由此导致这些设备在至少部分取决于平台 20 速度的预定位置和/或以预定时间间隔获取或采集图像。

图像和数据获取软件 90 按照需要对前述信号进行解码并将其存储在存储器 82 中，并且使得该数据信号与相应的图像信号 48a 和 48b 相关联。因此，可以知道图像采集设备 32a 和 32b 采集的每个图像的海拔高度，就俯仰、滚动和偏航而言的定向，图像采集设备 32a 和 32b 相对于表面 31 的位置，即，经度和纬度。

经由图像采集路线驾驶或者以其它方式引导平台 20，所述图像采集路线经过表面 31 的特定区域上方，例如地球或另一行星表面的预定区域。优选地，平台 20 的图像采集路线与感兴趣区域的至少一个边界成直角。平台 20 和/或图像采集设备 32a，32b 经过感兴趣区域上方的次数至少部分取决于该区域的大小以及在采集的图像中所需的细节量。以下更具体地描述平台 20 的图像采集路线的特定细节。

当平台 20 经过感兴趣区域上方时，大量倾斜图像被图像采集设备 32a 和 32b 采集。本领域的普通技术人员将会理解，以预定的图像获取时间间隔，图像采集设备 32a 和 32b 采集或获取图像，所述时间间隔至少部分取决于平台 20 的速度。

图像采集计算机系统 46 的存储器 82 通过 I/O 端口 88 接收并存储对应于获取的每个图像的图像数据信号 48a 和 48b。类似地，图像采集计算机系统 46 的存储器 82 通过 I/O 端口 88 接收并存储对应于采集的每个图像的数据信号(即，图像数据信号 48，位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66，68，航向信号 72 和海拔高度信号 74)。因此，在采集每个图像的准确时刻，图像采集设备 32a 和 32b 相对于表面 32 的位置被记录在存储器 82 中，

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并且与相应的采集图像相关联。

如图 1 所示，图像采集设备 32a 和 32b 相对于地球的位置对应于正交图像 102 的最底点 N。因此，正交图像 102 的最底点 N 的精确地理位置由位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66，68，航向信号 72 和海拔高度信号 74 表示。一旦正交图像 102 的最底点 N 已知，可以用公知的方式确定图像 102 内任何其它像素或点的地理位置。

当图像采集设备 32a 和 32b 采集诸如倾斜图像 104a 和 104b(图 1)的倾斜图像时，图像采集设备 32a 和 32b 相对于表面 31 的位置类似地分别由位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66，68，航向信号 72，海拔高度信号 74 和图像采集设备 32a 和 32b 的主轴线 A_1 和 A_2 的已知偏角 θ 表示。

特别应当注意的是，校准过程使图像和数据获取软件 90 能够结合校正系数和/或能够对图像采集设备 32 固有的或由其引起的任何误差进行校正，例如由于校准的焦距，传感器尺寸，径向畸变，主点偏移，和对准引起的误差。

图像和数据获取软件 90 产生并在存储器 82 中存储一个或多个输出图像和数据文件 120。更具体地，图像和数据获取软件 90 将图像数据信号 48a，48b 和定向数据信号(即，图像数据信号 48，位置信号 56，速度信号 58，时间数据信号 62，俯仰、滚动和偏航信号 64，66，68，航向信号 72 和海拔高度信号 74)转换为计算机可读的输出图像和数据文件 120。如图 4 所示，输出图像和数据文件 120 包含对应于采集的倾斜图像的多个采集图像文件 I_1，I_2，…，I_n，和与之对应的位置数据 C_{PD1}，C_{PD2}，…，C_{PDn}。

图像和数据文件 120 的图像文件 I_1，I_2，…，I_n 实际上以计算机可读的任何图像或图形文件格式被存储，例如 JPEG，TIFF，GIF，BMP，或者 PDF 文件格式，并且与同样作为计算机可读数据存储的位置数

据 C_{PD1}，C_{PD2}，...，C_{PDn} 相互参照。可选地，位置数据 C_{PD1}，C_{PD2}，...，C_{PDn} 以公知的方式嵌入到相应的图像文件 I_1，I_2，...，I_n 中。然后由图像和数据获取软件 90 或者由后处理过程对图像数据文件 120 进行处理，以校正误差，例如由于飞行路线偏移导致的误差和本领域普通技术人员公知的其它误差。之后，图像数据文件 120 准备好用于显示所采集图像中描述的物体，并对所采集图像中描述的物体及物体之间进行测量，包括该物体的高度测量。

现在参考图 5，图像显示和测量计算机系统 130，例如传统的台式个人电脑或者警车中的移动电脑终端，包括存储器 132，输入设备 134a 和 134b，显示设备 136，和网络连接器 138。图像采集计算机系统 130 运行图像显示和分析软件 140，该软件存储在存储器 132 中。存储器 132 包括，例如非易失性只读存储器，随机存取存储器，硬盘存储器，移动存储卡和/或其它合适的记忆体存储设备和/或介质。输入设备 134a 和 134b，例如鼠标，键盘，控制杆等，允许数据的输入，并使用户与图像显示和测量计算机系统 130 运行的图像显示和分析软件 140 之间能够进行交互作用。显示设备 136，例如液晶显示器或阴极射线管，向图像显示和测量计算机系统 130 的用户显示信息。网络连接器 138 将图像显示和测量计算机系统 130 连接到网络(未示出)，例如局域网，广域网，因特网和/或万维网。

现在参考图 6，在使用中，运行图像显示和分析软件 140 的图像显示和测量计算机系统 130 访问一个或多个例如通过网络连接器 138，软盘驱动器，移动存储卡或其它适当方式读入存储器 132 中的输出图像和数据文件 120。此后，在图像显示和分析软件 140 的控制下，输出图像和数据文件 120 的一个或多个采集图像 I_1，I_2，...，I_n 作为显示倾斜图像 142 被显示。在大约相同的时间，对应于显示倾斜图像 142 的一个或多个数据部分 C_{PD1}，C_{PD2}，...，C_{PDn} 被读入到存储器 132 的可访问部分。

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特别应当注意的是，基本上当采集时对显示倾斜图像 142 进行显示，即显示的图像 142 没有针对任何坐标系弯曲或拟合，也没有被正交校正。图像显示和分析软件 140 并不为了能够测量图像中显示的物体而针对一个坐标系弯曲显示的图像 142，而是通常通过参考输出图像和数据文件 120 的数据部分 C_{PD1}，C_{PD2}，…，C_{PDn} 和使用一个或多个下文中将具体说明的投影方程计算那些所选像素的位置和/或地理位置，来确定仅根据需要而选择的或“在空中”选择的像素的地理位置。

通常，显示和测量计算机系统 130 的用户通过选择图像显示和分析软件 140 中提供的几个可用测量模式中的一个，对显示在显示倾斜图像 142 中的物体及其之间进行测量。用户例如通过访问一系列下拉菜单或工具栏 M，或者通过键盘命令选择所需的测量模式。图像显示和分析软件 140 提供的测量模式包括，例如，距离模式，其能够测量两个或多个选择点之间的距离；面积模式，其能够测量由若干选择的和互连的点包围的面积；高度模式，其能够测量两个或多个选择点之间的高度；和标高模式，其能够测量一个选择点相对于一个或多个其它选择点的标高变化。

当选择所需的测量模式之后，图像显示和分析软件 140 的用户用输入设备 134a，134b 中的一个在显示图像 142 上选择起始点或开始像素 152 和结束点或像素 154，并且图像显示和分析软件 140 自动计算和显示探索量(quantity sought)，例如开始像素 152 和结束像素 154 之间的距离。

当用户选择开始点/像素 152 时，由图像显示和分析软件 140 计算表面 31 上与之对应的点的地理位置，所述图像显示和分析软件 140 利用与被显示的特定图像对应的输出图像和数据文件 120 的数据部分 C_{PD1}，C_{PD2}，…，C_{PDn}，运行一个或多个投影方程。然后，图像显示和分析软件 140 将与像素 152 对应的表面 31 上的点的经度和纬度

显示在显示器 136 上，例如，在显示图像 142 上，靠近选择点/像素叠加经度和纬度，或在显示器 136 上其它位置的弹出显示框中叠加经度和纬度。用户重复同样的过程，以选择结束像素/点 154，并且图像显示和分析软件 140 重复同样的过程，以检索和显示经度和纬度信息。

通过确定每个"在空中"选择的像素 152，154 的地理位置，分别完成起始和结束点/像素 152，154 之间距离的计算。检索与显示图像对应的输出图像和数据文件 120 的数据部分 C_{PD1}，C_{PD2}，…，C_{PDn}，然后确定与每个所选像素对应的表面 31 上点的地理位置。与所选像素对应的地理位置之间的差异决定了像素之间的距离。

作为如何确定显示倾斜图像 142 内给定点或像素的地理位置的例子，我们将假设显示图像 142 对应于正交图像 104(图 1)。图像显示和分析软件 140 的用户选择像素 154，为了简便，该像素对应于倾斜图像 104a 的中心 C(图 1)。如图 1 所示，线 106 沿着水平面 G，从其上位于图像采集设备 32a 正下方的点 108 延伸到倾斜图像 104a 的近边界或边缘 108 的中心 C。主轴线 A_1 的延伸线与中心 C 相交。角 φ 是在线 106 与主轴线 A_1 的延伸线之间形成的角。因此，形成一个三角形(未标示)，该三角形的顶点分别是图像采集设备 32a，点 108 和中心 C，该三角形的边分别是边 106，主轴线 A_1 的延伸线，以及点 108 和图像采集设备 32a 之间的垂线(虚线)110。

地平面 G 基本上是水平的、平坦的或不倾斜的地平面(其一般具有反映地形平均标高的标高)，因此上述的三角形包括边/线 110 和边/线 106 之间的直角。由于角 φ 和图像采集设备 32 的海拔高度(即，边 110 的长度)是已知的，因此可以通过简单的几何学计算该直角三角形的斜边(即，主轴线 A_1 的延伸线的长度)和剩下的另一边。而且，由于在与显示图像 142 对应的图像被采集的时刻，图像采集设备 32a 的精确位置已知，因此点 108 的纬度和经度也已知。知道按照上述计算的

边 106 的长度，能够通过图像显示和分析软件 140 确定与倾斜图像 104a 的中心 C 对应的像素 154 的准确地理位置。一旦知道了与像素 154 对应的点的地理位置，就可以利用已知相机特性来确定显示倾斜图像 142 中的任何其它像素的地理位置，例如焦距，传感器尺寸和长宽比，径向畸变和其它畸变项等。

通过利用公知算法确定所选像素的地理位置之间的差异，图像显示和分析软件 140 计算与显示图像 142 中两个或多个所选像素对应的两个或多个点之间的距离，所述算法例如为高斯公式和/或灭点(vanishing point)公式，这取决于选择的测量模式。通过与上述测量所选像素之间的距离基本类似的过程，来对显示或出现在显示图像 142 中的物体进行测量。例如，通过选择合适的/所需的测量模式，以及选择开始和结束像素，来测量出现在显示图像 142 中的诸如建筑物，河流，道路，以及实质上任何其它地理或人造结构的物体的长度，宽度和高度。

特别应当注意的是，在图像显示和分析软件 140 的距离测量模式中，开始和结束点/像素 152，154 之间的距离实质上可以沿任何路线确定，例如“直线”路线 P1，或者包括选择中间点/像素和一个或多个与之互连的“直线”段的路线 P2。

也特别应当注意的是，图像显示和分析软件 140 的距离测量模式根据“漫步地球”法确定所选像素之间的距离。“漫步地球法”产生了一系列互连的直线段，这些线段共同由路线 P1 和 P2 表示，所述路线 P1 和 P2 在所选像素/点之间延伸，并且落在或依照定义了方格状地平面的一系列互连小平面中的平面上。如以下将具体描述的，方格状地平面很接近地遵照或再现表面 31 的地形，因此路线 P1 和 P2 也很接近地遵照表面 31 的地形。通过沿着由方格状地平面模拟的地形测量距离，“漫步地球”法提供了比传统方法更精确和有用的选择点之间的距离测量，所述传统方法在平地或平均标高平面系统上弯曲图像，并

且沿平地或平面测量选择点之间的距离，基本上忽略点之间的地形变化。

例如，准备对在不平地形或者丘陵地形上铺路的合同进行投标的承包商，可以使用图像显示和分析软件 140 和由此提供的“漫步地球”测量法，来确定所包含道路的近似数量或面积。承包商可以从他或她自己的办公室获得道路的近似数量或面积，而不必派遣测绘队到现场获得必要的测量值。

与本发明提供的“漫步地球”法相比，当测量位于不平地形上的点和/或物体之间的距离时，以及当测量类似物体的尺寸和/或高度时，“平地”或平均标高距离计算法包含固有的不精确性。即使采集表面中的适度倾斜或坡度，也导致最底点的标高实际上相对于其上任何其它兴趣点的差值。因此，再次参考图 1，由线 106，主轴线 A_1 的延伸线，以及点 108 和图像采集设备 32a 之间的垂线(虚线)110 形成的三角形可能不是直角三角形。如果发生这种情况，假设该三角形是直角三角形的任何几何计算会包含误差，甚至兴趣点之间的较小的梯度或斜坡也会导致该计算结果成为近似值。

例如，如果表面 31 在最底点 N 和倾斜图像 104 的靠近边缘或底部边缘 108 的中心 C 之间向上倾斜，那么第二线 110 在其与水平或非倾斜表面 31 的交点之前的一点与表面 31 相交。如果中心 C 比最底点 N 高 15 英尺，并且具有 40°(40 度)偏角 θ，如果不对点之间的标高变化进行校正，那么计算的中心 C 的位置将偏差大约 17.8 英尺。

大体如上所述，为了至少部分地补偿标高的变化，和图像 142 中的物体及物体之间的测量产生的不精确性，图像显示和分析软件 140 按照需要参考显示图像 142 中和表面 31 上的点，与预先计算的、图 6 中表示为 160 的方格状或分成小面的地平面进行参照。方格状地平面 160 包括多个独立的小平面 162a，162b，162c 等，每个小平面与每个其它小平面互相连接，并且由具有各自标高的四个顶点(未标示，

但是以点示出)定义。小平面 162a，162b，162c 等中的相邻两个共用两个顶点。每个小平面 162a，162b，162c 等具有各自的间距和坡度。方格状地平面 160 基于各种数据和资源而产生，例如地形图，和/或数字光栅图形，测绘数据，和各种其它的资源。

通常，通过确定小平面 162a，162b，162c 等中的哪一个对应于感兴趣点，来计算显示图像 142 上感兴趣点的地理位置。因此，感兴趣点的位置基于小平面 162a，162b，162c 等的标高、间距和坡度特征计算，而不是基于平坦的或平均标高地平面计算。感兴趣点位于小平面 162a，162b，162c 等的平面内，只有在表面 31 的地形和其上感兴趣点的位置偏离这些平面的情况下，才会引入误差。通过对小平面 162a，162b，162c 等中的特定一个小平面内感兴趣点的标高进行双线性插值，并且在图像显示和分析软件 140 执行的位置计算中利用该以插值的标高，可以减小误差。

为了使用方块状地平面 160，图像显示和分析软件 140 利用改进的光线跟踪算法，来找到从图像采集设备 32a 或 32b 朝表面 31 和方块状地平面 160 投射光线的交点。该算法不仅确定了小平面 162a，162b，162c 等中的哪一个与该光线相交，而且确定了在小平面内的什么位置发生该相交。通过使用双线性插值，可以确定相当精确的地面位置。对于反向投影，使用方块状地平面 160 也利用双线性插值，得到输入地面位置的地面标高值。然后通过图像采集设备 32a 或 32b 的模型，将该标高和位置用于反向投影，以确定显示图像 142 中哪一个像素对应于给定位置。

更具体地，作为一个例子，通过将方块状地平面 160 叠加和/或拟合到表面 31 的至少一个诸如小山这样的部分 166，图像显示和分析软件 140 执行和/或计算点 164 的地理位置。应当注意，只有方块状地平面 160 及其小平面 162a，162b，162c 等中的一小部分，沿着表面 31 的部分 166 的轮廓显示。如上所述，小平面 162a，162b，162c

等中的每一个由四个顶点定义，每个顶点具有各自的标高，每个小平面具有各自的间距和坡度。如上所述，确定在小平面 162a，162b，162c 等的平面/表面(点 164(或其投影)位于该平面/表面上)上点 164 的具体位置。

优选地，在图像显示和测量计算机系统 130 以及图像显示和分析软件 140 的操作之外产生方块状地平面 160。更好地，方块状地平面 160 采用存储在图像显示和测量计算机系统 130 的和/或可访问存储器中较简单的数据表或查询表 168 的形式。计算典型地平面的许多小平面的所有顶点位置所需的计算资源，不一定在图像显示和测量计算机系统 130 中。因此，在不需要附加计算资源的情况下，图像显示和测量计算机系统 130 与传统个人电脑的应用兼容，并可由传统的个人电脑执行。

在图像显示和测量计算机系统 130 之外计算方块状地平面 160，实际上能够使方块状地平面 160 中包含任何级别的细节，即，由小平面 162a，162b，162c 等中的每一个覆盖的或对应的尺寸和/或面积，可以按照需要变大或变小，而不会明显地增加计算时间，减慢操作，也不会显著增加图像显示和测量计算机系统 130 和/或图像显示和分析软件 140 所需的资源。显示和测量计算机系统 130 因此可以是较基本的和不复杂的计算机系统。

小平面 162a，162b，162c 等的尺寸在特定的显示图像 142 中是一致的。例如，如果显示图像 142 对应于在前景中大约 750 英尺宽和大约 900 英尺深的面积，那么该图像可以被分为大约 50 平方英尺的小平面，因此在宽度上产生了大约 15 个小平面，在深度上产生了 18 个小平面。可选择地，小平面 162a，162b，162c 等的尺寸就包含于其中的像素数量而言是一致的，即，每个小平面具有相同数量的像素宽度和相同数量的像素深度。因此，在像素密度最大的显示图像 142 的前景中的小平面，在尺寸上小于像素密度最低的显示图像 142 的背景

中的小平面。由于希望在像素密度最大的显示图像的前景中进行大多数的测量，与尺寸一致的小平面相比，产生包含的像素数量一致的小平面具有的优点是，在显示图像 142 的前景中提供了更精确的测量。

使用像素作为基础来定义小平面 162a，162b，162c 等的尺寸的另一优点是，位置计算(像素位置到地面位置)较简单。用户操作图像显示和测量计算机系统 130，以选择给定小平面中的像素，图像显示和分析软件 140 查询与选择像素对应的小平面的数据，如上所述计算所选像素的标高，该标高用于位置计算中。

通常，本发明采集倾斜图像的方法，将例如国家这样的感兴趣区域划分为尺寸基本一致的区，例如面积大约为一平方英里的区。这样做便于制定飞行计划，以采集覆盖每一英寸感兴趣区域的倾斜图像，并且组织和命名这些区和/或其图像，以容易地标识，存储和检索(在本领域中被称为“分区”法)。因为任何感兴趣的地理区域的边缘，例如国家，极少落在整齐划一的平分英里边界，所以本发明采集倾斜图像的方法提供了比感兴趣区域中的平方英里数要多的区——多出多少主要取决于该国家边界的长度，以及边界的平直或曲折程度如何。典型地，可以预期边界的每二到三英里具有一个额外的区。因此如果国家或其它感兴趣区域约为 20 英里乘 35 英里，或者为 700 平方英里，那么该面积将被分为大约 740－780 个区。

通常，本发明采集倾斜图像的方法从至少两个罗盘方向采集倾斜图像，并且从至少这两个罗盘方向提供感兴趣区域的完全覆盖。现在参考图 7 和 8，显示了本发明用于采集倾斜图像的方法的第一实施例。为了清楚，图 7 和 8 基于仅具有一个图像采集设备的系统。然而，应当理解可以使用两个或多个图像采集设备。

图像采集设备在每次穿越区域 200 期间采集一个或多个倾斜图像。如上所述，图像采集设备以一个角度瞄准区域 200，以采集倾斜图像。图像捕捉设备和/或平台以类似于修剪草坪的方式来回地穿越

区域 200，以保证区域 200 的双重覆盖。

更具体地，图像捕捉设备 32 和/或平台 20 沿着第一路线 202 穿越区域 200，由此采集区域 200 的区 202a，202b 和 202c 的倾斜图像。然后图像捕捉设备 32 和/或平台 20 沿着第二路线 204 穿越区域 200，由此采集区域 200 的区 204a，204b 和 204c 的倾斜图像，其中所述第二路线 204 与所述第一路线 202 平行且间隔一定距离，并且与其成 180°(180 度)的相反方向。通过比较图 7 和 8，可以看出区域 200 的区 207(图 8)被从第一方向或视角采集的图像 202a-c 覆盖，且被从第二方向或视角采集的图像 204a-c 覆盖。同样，区域 200 的中间区被 100%(百分之一百)双重覆盖。重复沿着平行于路线 202 和 204 的相反路线通过或穿越区域 200 的上述模式，直到整个区域 200 被至少一个从互相平行、由区域 200 的尺寸规定的距离互相间隔并且沿着与路线 202 和 204 相同方向的路径采集的倾斜图像完全覆盖为止，从而从那些视角/方向百分之一百双重覆盖区域 200。

如果需要，为了增强细节，两个附加的相反并平行的第三和第四路线 206 和 208 分别覆盖区域 200，如图 9 和 10 所示，路线 206 和 208 垂直于路线 202 和 204。因此图像捕捉设备 32 和/或平台 20 沿着第三路线 206 穿越区域 200，以采集区域 200 的区 206a，206b 和 206c 的倾斜图像，然后，沿着第四路线 208 穿越，以采集区域 200 的区 208a，208b 和 208c 的倾斜图像，所述第四路线 208 与第三路线 206 平行，间隔一定距离并且方向相反。类似地重复沿着平行于路线 206 和 208 的相反路线通过或穿越区域 200 的上述模式，直到整个区域 200 被至少一个从平行于、由区域 200 的尺寸规定的距离互相间隔、且与路线 206 和 208 相同方向的路径采集的倾斜图像完全覆盖为止，从而从那些视角/方向百分之一百双重覆盖区域 200。

如上所述，图像捕捉设备 32 和/或平台 20 沿着预定路线通过或穿越区域 200。然而，应当理解，图像捕捉设备和/或平台 20 并不一定

直接通过或穿越区域200，而是可以通过或穿越与区域200邻近、接壤，甚至一定程度上脱离区域200的区域，以确保正在被成像的区域200的区落在图像采集设备的图像采集范围内。如图7所示，路线202是这样的路线，其不直接经过区域200上方，但是仍采集其倾斜图像。

本发明能够以各种级别的分辨率和地面取样距离采集图像。第一级别的细节，之后称为社区级，具有例如约为每个像素2英尺的地面取样距离。对于正交社区级图像，地面取样距离在整个图像中基本保持恒定。正交社区级图像用足够的交叠进行采集，以提供立体双层覆盖。对于倾斜社区级图像，地面取样距离变化，例如，从图像前景中的大约每个像素1英尺，到图像中景中的大约每个像素2英尺，以及到图像背景中的大约每个像素4英尺。倾斜社区级图像用足够的交叠进行采集，从而典型地，由至少两个从每个罗盘方向采集的倾斜图像覆盖每个感兴趣的区域。每个区大约采集10个倾斜社区级图像。

第二级别的细节，之后称为邻居级，其明显地比社区级图像更详细。邻居级图像具有例如约为每个像素6英寸的地面取样距离。对于正交邻居级图像，地面取样距离基本保持恒定。倾斜邻居级图像具有的地面取样距离，例如，从图像前景中的大约每个像素4英寸，到图像中景中的大约每个像素6英寸，以及到图像背景中的大约每个像素10英寸。倾斜邻居级图像用足够的交叠进行采集，从而典型地，由至少两个从每个罗盘方向采集的倾斜图像覆盖每个感兴趣的区域，从而相对的罗盘方向提供了互相之间的100%交叠。每个区大约采集一百(100)个倾斜区域图像。

特别应当注意的是，从所有四个罗盘方向采集倾斜社区级和/或邻居级图像，保证了图像中的每个点将会出现在至少一个采集的倾斜图像的前景或者下部中，在图像的前景或下部中地面采样距离最小且图像细节最大。

在所示实施例中，图像采集和地理定位系统30包括陀螺仪，罗盘

和高度计。然而，应当理解，本发明的图像采集和地理定位系统可替代地可以构造成：例如，从 GPS 和 INU 信号/数据推导和/或计算海拔高度，俯仰，滚动和偏航，和罗盘导航，实际上，由此导致不再必需一个或多个陀螺仪，罗盘和高度计。

在所示的实施例中，图像采集设备相对于水平面具有相等偏角。然而，应当理解，图像采集设备的偏角不必相等。

在所示的实施例中，图像采集计算机系统运行图像和数据获取软件，该图像和数据获取软件将通用的或单独的图像采集信号发送到图像采集设备，由此促使那些设备获取或采集图像。然而，应当理解，本发明可替代地可以构造成，在不同的时刻和/或以不同的时间间隔，分别促使图像采集设备采集图像。

在所示的实施例中，本发明的方法采集倾斜图像，以从基本上彼此相对、即互相成 180°(180 度)的路线/视角提供对感兴趣区域的双重覆盖。然而，应当理解，本发明的方法可替代地可以构造成，从大致和/或基本互相垂直的路线/视角提供双重覆盖。

尽管以具有的优选设计描述了本发明，但是在该公开的精神和范围内，本发明可以被进一步修改。因此，该公开意味着包含其中公开的结构和元素的任何等价物。另外，该公开意味着包含使用其中公开的一般原理的本发明的任何变化，使用或修改。而且，该公开意味着包含在相关领域中的已知或惯用实施范围内，并且落入附加权利要求的限制内的本公开主旨的引申。

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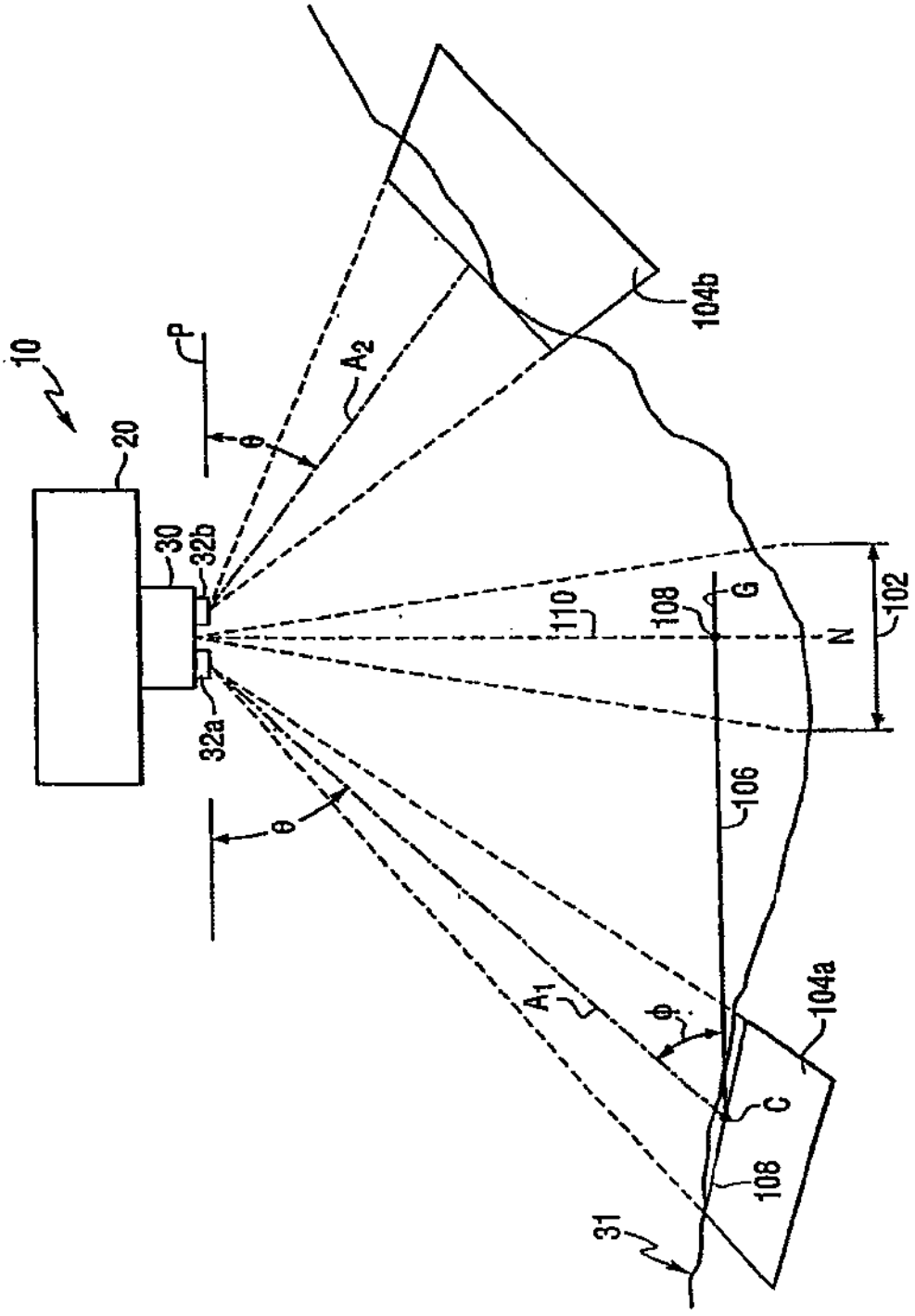


图 1

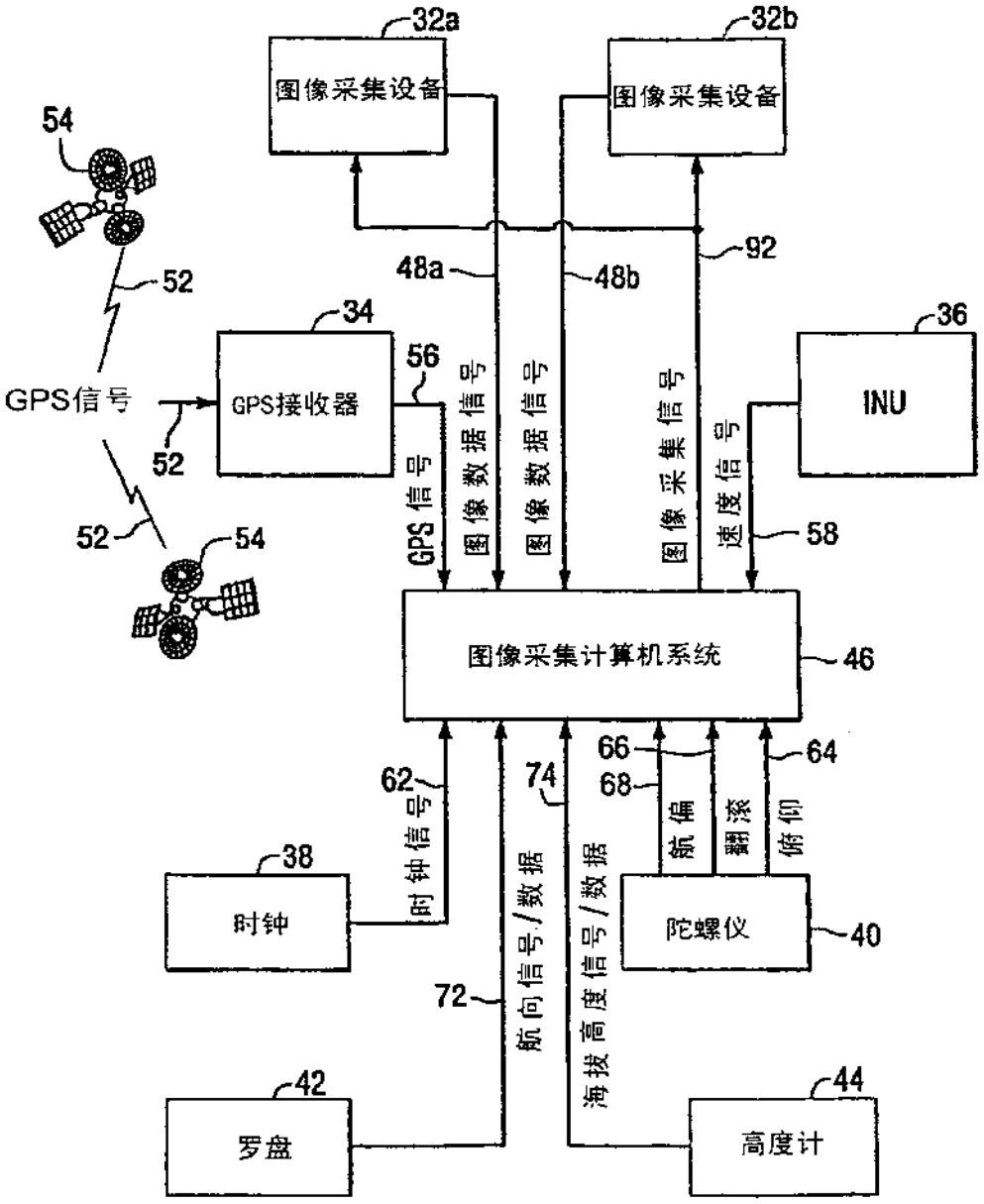

32a
图像采集设备
32b
图像采集设备
54
52
GPS信号
52
34
GPS接收器
56
52
54
48a
48b
92
36
INU
GPS信号
图像数据信号
图像数据信号
图像采集信号
速度信号
58
图像采集计算机系统
46
62
时钟信号
38
时钟
74
海拔高度信号/数据
72
航向信号/数据
66
68
航偏
翻滚
64
俯仰
陀螺仪
40
42
罗盘
44
高度计

图2

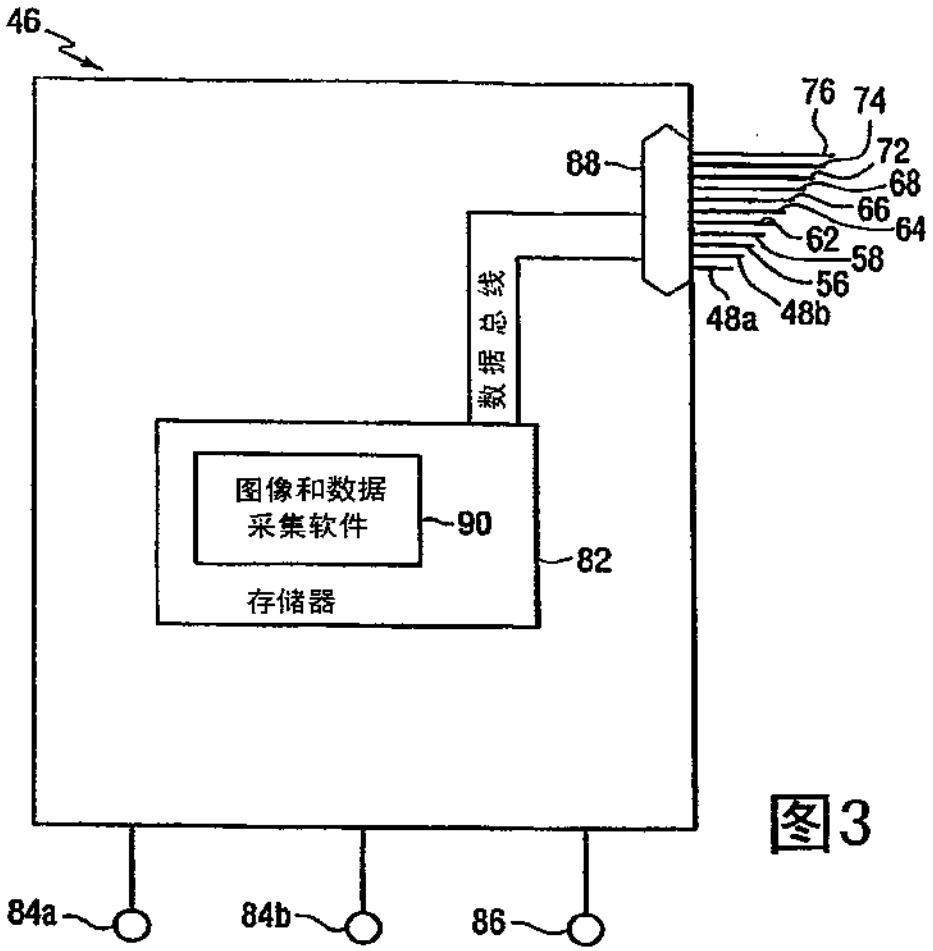

46
76
74
72
68
66
64
62
58
56
88
48a
48b
数据总线
图像和数据
采集软件
90
82
存储器
84a
84b
86

图3

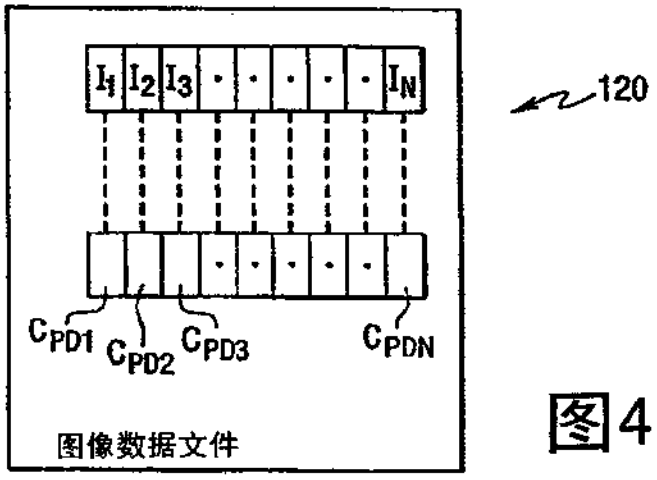

I1 I2 I3 · · · · · IN
120
CPD1 CPD2 CPD3 CPDN
图像数据文件

图4

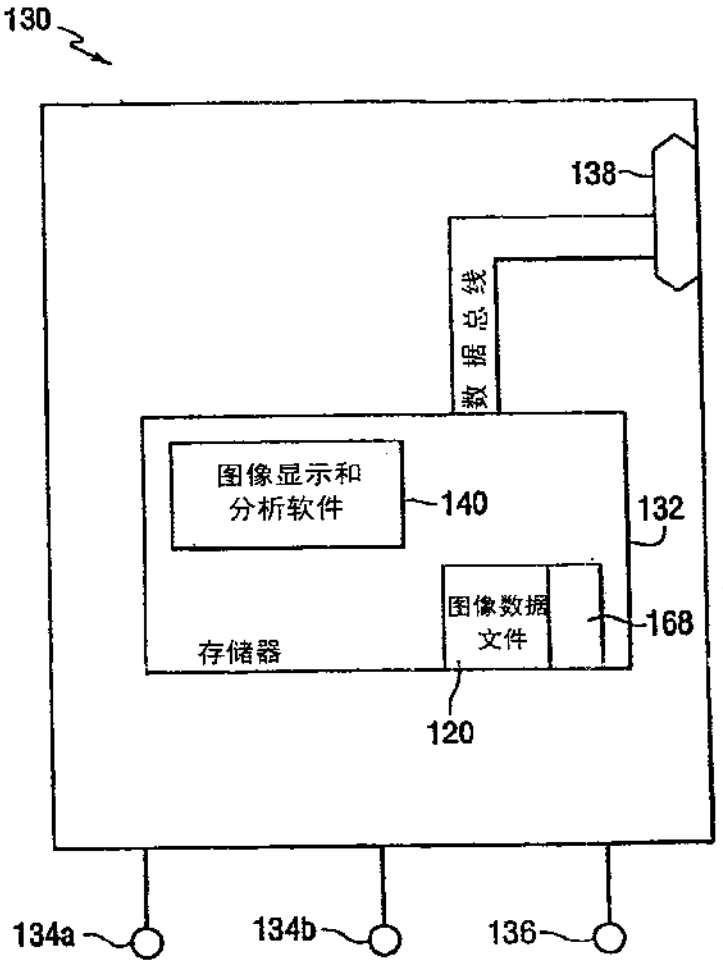

130
138
数据总线
图像显示和
分析软件
140
132
图像数据
文件
168
存储器
120
134a
134b
136

图5

Roofr Exhibit 1002, Page 375

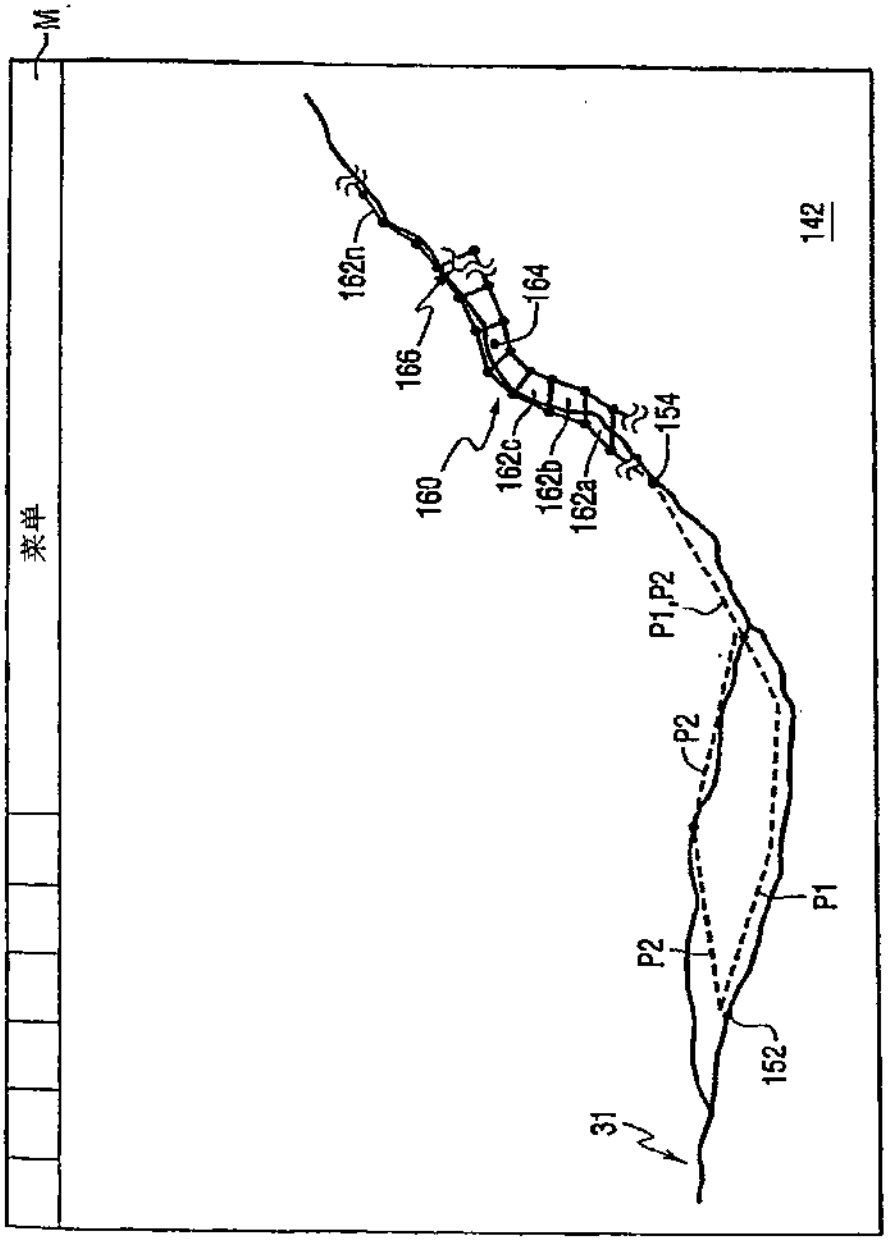


图6

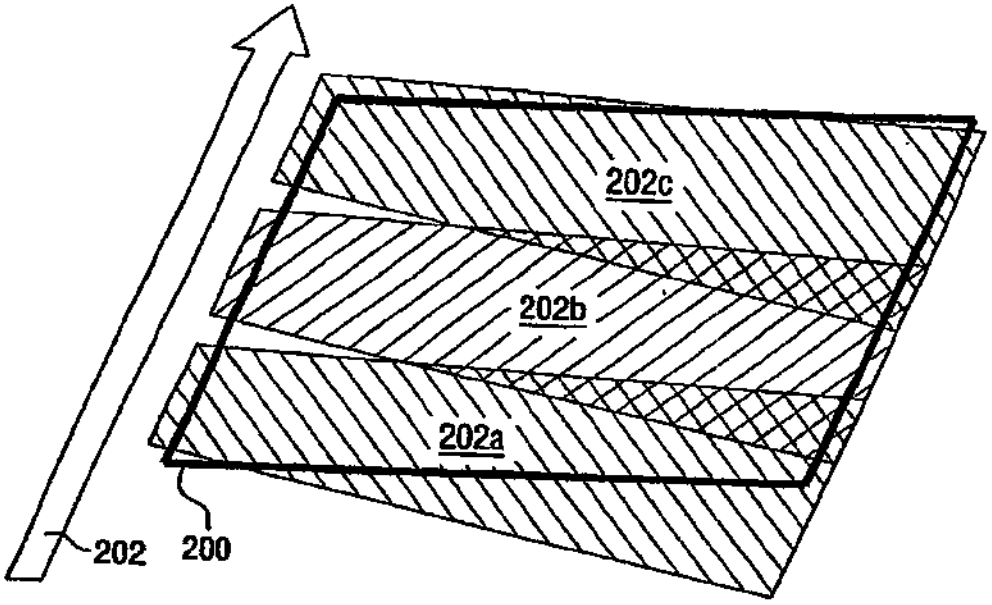


图7

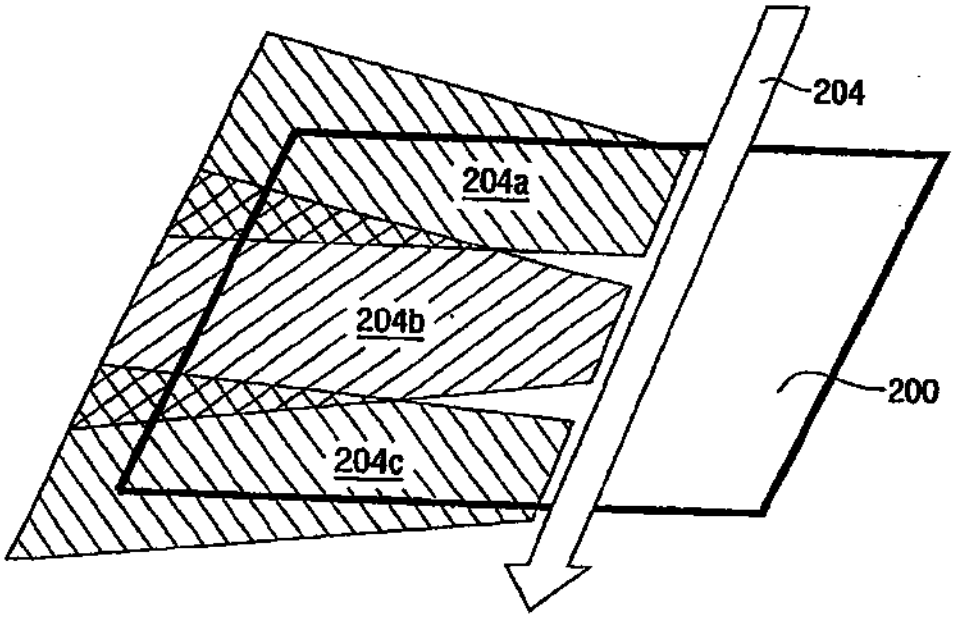


图8

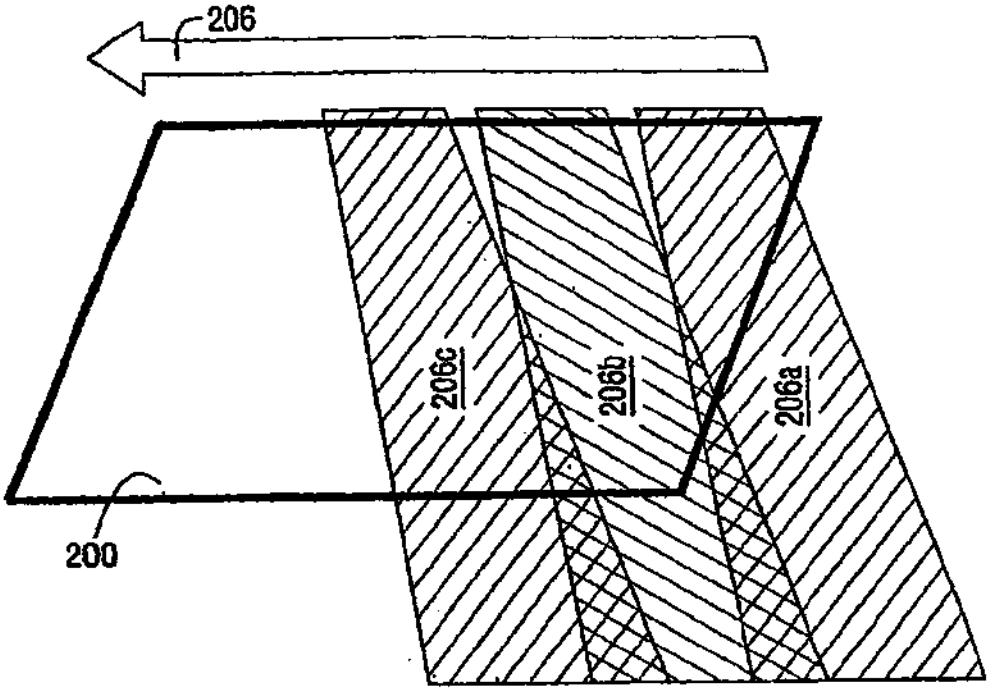


图9

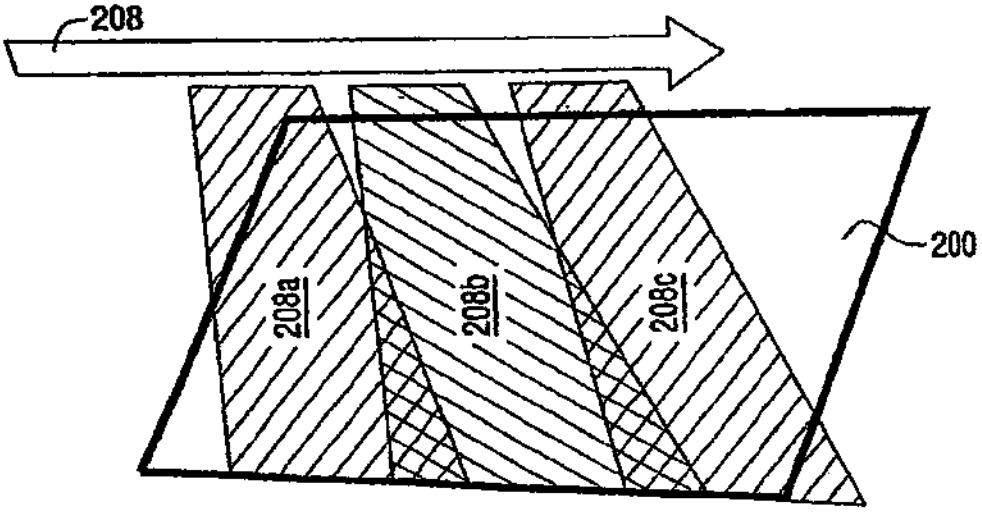


图10

Method and apparatus for capturing, geolocating and measuring oblique images

Publication number:	BR0316110 (A)
Publication date:	2005-09-27
Inventor(s):	SCHULTZ STEPHEN; GIUFFRIDA FRANK; GRAY ROBERT; MONDELLO CHARLES
Applicant(s):	PICTOMETRY INTERNAT CORP [US]
Classification:	
- International:	***G01C11/02***; G01C11/00; (IPC1-7): G06K9/40
- European:	G01C11/02
Application number:	BR20030016110 20031107
Priority number(s):	US20020425275P 20021108; WO2003US35528 20031107

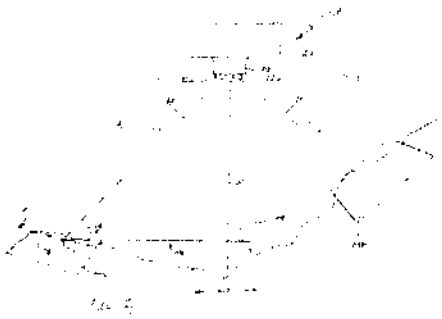
Also published as:

EP1418402 (A1)
EP1418402 (B1)
WO2004044692 (A2)
WO2004044692 (A3)
MXPA05004987 (A)
JP2006505794 (T)
ES2266704 (T3)
DK1418402 (T3)
DE60306301 (T2)
CN1735897 (A)
CA2505566 (A1)

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Abstract of BR 0316110 (A)

"SISTEMAS PARA CAPTAR IMAGENS E DADOS DE GEOLOCALIZAçãO CORRESPONDENTES àS MESMAS E PARA VISUALIZAR, GEOLOCALIZAR E EFETUAR MEDIçõES COM BASE EM IMAGENS OBLIQUAS CAPTADAS E MéTODOS DE FAZER MEDIçõES DENTRO DE UMA IMAGEM OBLIQUA VISUALIZADA E DE CAPTAR IMAGENS OBLIQUAS DE UMA áREA DE INTERESSE". Um sistema computadorizado para exibição, geolocalização e tomada de medições de imagens obliquas captadas inclui um arquivo de dados acessivel pelo sistema de computador. O arquivo de dados inclui uma pluralidade de arquivos de imagem correspondentes a uma pluralidade de imagens obliquas captadas, e dados posicionais correspondentes às imagens. Software de exbição e análise de imagem é executado pelo sistema para leitura do arquivo de dados e exbir pelo menos uma parte das imagens obliquas captadas ; O software recupera os dados posicionais para um ou mais pontos selecionados pelo usuário sobre a imagem exbida, e calcula uma distância de separação entre quaisquer dois ou mais pontos selecionados. O cálculo da distância de separação é selecionável pelo usuário para determinar varios parâmetros inclusive distância linear entre, área abrangida dentro, elevação relativa de, e diferença de altura entre pontos selecionados.



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Method and apparatus for capturing, geolocating and measuring oblique images

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Description of corresponding document: **EP 1418402 (A1)**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

[0002] The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

[0003] Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

[0004] Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

[0005] Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

[0006] Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

[0007] Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

[0008] Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

[0009] Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which measurements can be made and reducing the accuracy of any such measurements.

[0010] Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein.

[0011] Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique images.

[0012] Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

[0013] Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

[0014] The present invention provides a method and apparatus for capturing, displaying, and making measurements of objects and distances between objects depicted within oblique images.

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[0015] The present invention comprises, in one form thereof, a computerized system for displaying, geolocating, and taking measurements from captured oblique images. The system includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein: FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby; FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1; FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2; FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1; FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1; FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement of and between objects depicted in such an image; FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention; FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

[0017] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

[0019] Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

[0020] Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

[0021] Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as will be more particularly described hereinafter.

[0022] As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A1 and A2, and are mounted to platform 20 such that axes A1 and A2 are each at an angle of declination &thetas; relative to a horizontal plane P. Declination angle &thetas; is virtually any oblique angle, but is preferably from approximately 20 DEG (twenty degrees) to approximately 60 DEG (sixty degrees) and is most preferably from approximately 40 DEG (forty degrees) to approximately 50 DEG (fifty degrees).

[0023] GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0024] INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0025] Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

[0026] Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by mage-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0027] Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

[0028] Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

[0029] As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer,

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includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

[0030] Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

[0031] In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

[0032] Image and data acquiring software 90 decodes as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

[0033] Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

[0034] As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

[0035] Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

[0036] As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point N of orthogonal image 102. Thus, the exact geo-location of the nadir point N of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir point N of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

[0037] When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination &thetas; of the primary axes A1 and A2 of image-capturing devices 32a and 32b, respectively.

[0038] It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

[0039] Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I1, I2, ... , In corresponding to captured oblique images, and the positional data CPD1, CPD2, ... , CPDn corresponding thereto.

[0040] Image files I1, I2, ..., In of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data CPD1, CPD2, ..., CPDn which is also stored as computer-readable data. Alternatively, positional data CPD1, CPD2, ..., CPDn is embedded within the corresponding image files I1, I2, . .., In in known manner. Image data files 120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

[0041] Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with image display and analysis software 140 being executed by image display and measurement computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

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[0042] In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images I1, I2, ... , In of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions CPD1, CPD2, ... CPDn corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

[0043] It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or tilted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions CPD1, CPD2, . . , CPDn of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

[0044] Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars M, or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

[0045] After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel 154.

[0046] When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions CPD1, CPD2, ..., CPDn of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

[0047] The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions CPD1, CPD2, . . , CPDn of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

[0048] As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142 corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 154 which, for simplicity, corresponds to center C (Fig. 1) of oblique image 104a. As shown in Fig. 1, line 106 extends along horizontal plane G from a point 108 thereon that is directly below image-capturing device 32a to the center C of the near border or edge 108 of oblique image 104a. An extension of primary axis A1 intersects with center C. Angle DIAMETER is the angle formed between line 106 the extension of primary axis A1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center C, and having sides 106, the extension of primary axis A1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

[0049] Ground plane G is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle DIAMETER and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A1) and remaining other side of the right triangle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center C of oblique image 104a to be determined by image display and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

[0050] The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

[0051] It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path P1 or a path P2 that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected therewith

[0052] It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths P1 and P2, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths P1 and P2 also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

[0053] For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the

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approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

[0054] In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

[0055] For example, if surface 31 slopes upward between nadir point N and center C at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center C is fifteen feet higher than nadir point N and with a declination angle &thetas; equal to 40 DEG (forty degrees), the calculated location of center C would be off by approximately 17.8 feet without correction for the change in elevation between the points.

[0056] As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant inaccuracies in the measurement of and between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, survey data, and various other sources.

[0057] Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc. within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

[0058] To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

[0059] More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

[0060] Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

[0061] Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

[0062] The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

[0063] Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed above, and that elevation is used within the location calculation.

[0064] Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of

capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest - how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

[0065] The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

[0066] The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

[0067] More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180 DEG (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

[0068] If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

[0069] As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

[0070] The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

[0071] A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially constant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

[0072] It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

[0073] In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary. In fact,

[0074] In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

[0075] In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

[0076] In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180 DEG (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other

[0077] While the present invention has been described as having a preferred design, the invention can be further modified within the spirit and scope of this disclosure. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended

Roofr Exhibit 1002, Page 385

claims.

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Method and apparatus for capturing, geolocating and measuring oblique images

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Claims of corresponding document: **EP 1418402 (A1)**

1. A system for capturing images and geo-location data corresponding thereto, comprising: an image-capturing device, said image-capturing device capturing oblique images at image-capturing events, said image capturing device issuing image-data signals corresponding to captured images; at least one geo-locating device, each said at least one geo-locating device issuing a corresponding at least one geo-locating signal, each said at least one geo-locating signal being indicative at least in part of a geo-location of said image-capturing device during each image capturing event; and a computer system receiving and storing said image-data signals and said at least one geo-locating signal; and image and data acquiring software reading said image-data signals and said at least one geo-locating signal, said software associating each said image-data signal with a corresponding said at least one geo-locating signal for each image-capturing event.

2. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise at least one of: a clock issuing to said image-capturing computer system time data signals indicative of a time of each said image-capturing event; a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event; an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event; a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event; a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

3. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise: a clock issuing to said image-capturing computer system time data signals indicative of a time of each said image-capturing event; a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event; an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event; a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event; a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

4. The system of claim 1, further comprising correction data indicative of characteristics of said image-capturing device including focal length, sensor size, radial distortion, principal point offset and alignment, said image and data acquiring software utilizing said correction data to correct captured images.

5. The system of claim 1, further comprising an output data file created by said image and data acquiring software, said output data file including a plurality of image files and positional data corresponding to each of said plurality of image files.

6. The system of claim 1, further comprising a platform carrying said image-capturing device a predetermined distance above a surface of interest.

7. A computerized system for displaying, geolocating, and making measurements based upon captured oblique images, comprising: a computer system having a memory; an image and data file accessible by said system and including a plurality of image files corresponding to a plurality of captured oblique images, said image and data file further including positional data corresponding to said plurality of image files; image display and analysis software executed by said system for reading said image and data file and displaying at least a portion of the captured oblique images as a displayed image, said software retrieving said positional data of one or more selected points within said displayed image, said software calculating a separation distance between any two or more selected points within said displayed image.

8. The system of claim 7, further comprising a ground plane data file representing a tessellated ground plane, said ground plane data file accessible by said computer system, said ground plane data file representing a tessellated ground plane that closely approximates at least a portion of the terrain depicted within said captured oblique images.

9. The system of claim 8, wherein said tessellated ground plane further comprises a plurality of interconnected facets, each of said plurality of facets having a respective pitch and slope.

10. The system of claim 9, wherein said ground plane data file comprises a plurality of vertices, each of said plurality of vertices having respective elevations and defining corners of said plurality of interconnected facets, two of said plurality of vertices shared by each of said interconnected facets.

11. The system of claim 10, wherein said image display and analysis software identifies which of said plurality of facets corresponds to a selected point on said displayed image, and calculates an elevation of said selected point dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point, said image display and analysis software using said calculated elevation for calculating said separation distance between said selected point and one or more further selected points.

12. The system of claim 11, wherein said image display and analysis software calculates a height of an object within said displayed image by calculating the separation distance between two or more selected points.

13. The system of claim 8, wherein said tessellated ground plane is one of superimposed upon and fit to said displayed image.

14. The system of claim 7, wherein said image display and analysis software includes user-selectable measuring modes accessible through at least one of pull-down menus, toolbars and keyboard commands.

15. The system of claim 7, wherein each of said images were captured by an image-capturing device and at respective image capturing events, said positional data of said image and data file including: time data representing the time of each image-capturing event; location data representing the location of the image-capturing device at each image-capturing event; orientation data representing the orientation of the image-capturing device at each image-capturing event; correction data representing correction factors for the image-capturing device; and elevation data representing an average elevation of the surface captured by the image-capturing device.

16. The system of claim 15, wherein said location data includes latitude, longitude, and altitude of the image-capturing apparatus at each image-capturing event.

17. The system of claim 15, wherein said orientation data includes roll, pitch, yaw and heading of said image-capturing device at each image-capturing event.

18. The data set of claim 15, wherein said image-capturing device is a camera and said correction data includes at least one of focal length, sensor size, aspect ratio, principle point offset, distortion, and pixel pitch.

19. A computerized method for taking measurements within a displayed oblique image, comprising: selecting with an input device a starting point and an end point on the displayed image; retrieving from a data file positional data corresponding to said starting point and said end point; referencing a ground plane data file corresponding to a tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said tessellated ground plane closely matching a terrain of said displayed oblique image; connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

20. The method of claim 19, wherein said tessellated ground plane is superimposed upon said displayed oblique image.

21. The method of claim 19, comprising the further steps of: selecting with an input device one or more intermediate points on the displayed image; retrieving from said data file positional data corresponding to said one or more intermediate points; and connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and calculating the distance along said line segments between said starting and end points.

22. The method of claim 19, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

23. The method of claim 19, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

24. A computerized method for taking measurements from an oblique image displayed on a computer system, at least one input device connected to said computer system, an image data file accessible by said computer system, said image data file including captured images and positional data corresponding thereto, said computerized method comprising: placing the computer system into a desired one of a plurality of measurement modes, the desired measurement mode configured for calculating a desired measurement; selecting a starting point on the displayed image; retrieving the positional data corresponding to said starting point; selecting an end point on the displayed image; retrieving the positional data corresponding to said end point; and calculating the desired measurement dependent at least in part upon said positional data of said starting and end points.

25. The method of claim 24, comprising the further steps of: selecting one or more intermediate points on said displayed image; and retrieving the positional data corresponding to said intermediate points.

26. The method of claim 24, wherein said plurality of measurement modes comprise a distance measuring mode calculating a distance between two or more selected points, a height measuring mode calculating a height difference between two or more selected points, a relative elevation measurement mode calculating the difference in elevation of two or more selected points, and an area measurement mode calculating the area encompassed by at least three points.

27. A method of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said method comprising: subdividing the area of interest into a plurality of sectors; guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device; capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective; guiding the platform along a second path to thereby target said target sectors, capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective; repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

28. The method of claim 27, wherein said second path is substantially parallel relative to and 180 DEG (one-hundred and eighty degrees) from said first path;

29. The method of claim 28, wherein said second path is also spaced apart from said first path.

30. The method of claim 27, comprising the further steps of: guiding the platform along a third path to thereby target one or more target sectors with the image-capturing device, said third path being substantially perpendicular to said first and second paths; capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a third perspective; and repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

31. The method of claim 30, comprising the further steps of: guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180 DEG (one-hundred and eighty degrees) from said third path; capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

32. The method of claim 31, wherein said fourth path is also spaced apart from said third path.

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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 696 204 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.08.2006 Bulletin 2006/35

(51) Int Cl.:
G01C 11/02 *(2006.01)*

(21) Application number: **06012675.2**

(22) Date of filing: **07.11.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(30) Priority: **08.11.2002 US 425275 P**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
03025702.6 / 1 418 402

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Remarks:
This application was filed on 20 - 06 - 2006 as a divisional application to the application mentioned under INID code 62.

(54) Method and apparatus for capturing, geolocating and measuring oblique images

(57) A computerized system for displaying, geolocating, and taking measurements from captured oblique images includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

[0002] The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

[0003] Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

[0004] Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

[0005] Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

[0006] Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectfified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

[0007] Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

[0008] Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

[0009] Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing

the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which measurements can be made and reducing the accuracy of any such measurements.

[0010] Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein.

[0011] Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique images.

[0012] Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

[0013] Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

[0014] The present invention provides a method and apparatus for capturing, displaying, and making measurements of objects and distances between objects depicted within oblique images.

[0015] The present invention comprises, in one form thereof, a computerized system for displaying, geolocating, and taking measurements from captured oblique images. The system includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby;
FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1;
FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2;
FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1;
FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1;
FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement of and between objects depicted in such an image;
FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention;
FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

[0017] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

[0019] Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled

movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

[0020] Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

[0021] Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as will be more particularly described hereinafter.

[0022] As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A_1 and A_2, and are mounted to platform 20 such that axes A_1 and A_2 are each at an angle of declination θ relative to a horizontal plane P. Declination angle θ is virtually any oblique angle, but is preferably from approximately 20° (twenty degrees) to approximately 60° (sixty degrees) and is most preferably from approximately 40° (forty degrees) to approximately 50° (fifty degrees).

[0023] GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0024] INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0025] Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

[0026] Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by mage-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

[0027] Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

[0028] Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

[0029] As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer, includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

[0030] Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

[0031] In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

[0032] Image and data acquiring software 90 decodes as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

[0033] Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

[0034] As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

[0035] Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

[0036] As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point *N* of orthogonal image 102. Thus, the exact geo-location of the nadir point *N* of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir point *N* of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

[0037] When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination θ of the primary axes A_1 and A_2 of image-capturing devices 32a and 32b, respectively.

[0038] It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

[0039] Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I_1, I_2, ..., I_n corresponding to captured oblique images, and the positional data C_{PD1}, C_{PD2}, ... , C_{PDn} corresponding thereto.

[0040] Image files I_1, I_2, ... , I_n of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data C_{PD1}, C_{PD2}, ... , C_{PDn} which is also stored as computer-readable data. Alternatively, positional data C_{PD1}, C_{PD2}, ..., C_{PDn} is embedded within the corresponding image files I_1, I_2, ..., I_n in known manner. Image data files

120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

[0041] Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with image display and analysis software 140 being executed by image display and measurement computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

[0042] In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images $I_1, I_2, \ldots, I_n$ of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions $C_{PD1}, C_{PD2}, \ldots, C_{PDn}$ corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

[0043] It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or fitted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions $C_{PD1}, C_{PD2}, \ldots, C_{PDn}$ of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

[0044] Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars M_i or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

[0045] After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel 154.

[0046] When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions $C_{PD1}, C_{PD2}, \ldots, C_{PDn}$ of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

[0047] The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions $C_{PD1}, C_{PD2}, \ldots, C_{PDn}$ of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

[0048] As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142 corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 154 which, for simplicity, corresponds to center C (Fig. 1) of oblique image 104a. As

shown in Fig. 1, line 106 extends along horizontal plane G from a point 108 thereon that is directly below image-capturing device 32a to the center C of the near border or edge 108 of oblique image 104a. An extension of primary axis A_1 intersects with center C. Angle Ø is the angle formed between line 106 the extension of primary axis A_1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center C, and having sides 106, the extension of primary axis A_1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

[0049] Ground plane G is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle Ø and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A_1) and remaining other side of the right triangle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center C of oblique image 104a to be determined by image display and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

[0050] The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

[0051] It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path *P1* or a path *P2* that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected therewith.

[0052] It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths *P1* and *P2*, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths *P1* and *P2* also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

[0053] For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

[0054] In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A_1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

[0055] For example, if surface 31 slopes upward between nadir point *N* and center C at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center C is fifteen feet higher than nadir point *N* and with a declination angle θ equal to 40° (forty degrees), the calculated location of center C would be off by approximately 17.8 feet without correction for the change in elevation between the points.

[0056] As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant

inaccuracies in the measurement of and between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, survey data, and various other sources.

[0057] Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc, within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

[0058] To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

[0059] More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

[0060] Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

[0061] Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

[0062] The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

[0063] Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed

above, and that elevation is used within the location calculation.

[0064] Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest — how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

[0065] The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

[0066] The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

[0067] More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180° (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

[0068] If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

[0069] As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

[0070] The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

[0071] A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially con-

stant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

[0072] It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

[0073] In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary. In fact,

[0074] In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

[0075] In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

[0076] In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180° (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other.

[0077] While the present invention has been described as having a preferred design, the invention can be further modified within the spirit and scope of this disclosure. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended claims.

Claims

1. A method of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said method comprising:

   subdividing the area of interest into a plurality of sectors;
   guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device;
   capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective; guiding the platform along a second path to thereby target said target sectors;
   capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective; repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and
   recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

2. The method of claim 1, wherein said second path is substantially parallel relative to and 180° from said first path.

3. The method of claim 1, wherein said second path is also spaced apart from said first path.

4. The method of claim 1, comprising the further steps of:

   guiding the platform along a third path to thereby target one or more target sectors with the image-capturing

device, said third path being substantially perpendicular to said first and second paths;
capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a third perspective; and
repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

5. The method of claim 4, comprising the further steps of:

guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180° from said third path;
capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and
repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

6. The method of claim 5, wherein said fourth path is also spaced apart from said third path.

7. A computerized method for taking measurements from an oblique image displayed on a computer system, at least one input device connected to said computer system, an image data file accessible by said computer system, said image data file including captured images and positional data corresponding thereto, said computerized method comprising:

placing the computer system into a desired one of a plurality of measurement modes, the desired measurement mode configured for calculating a desired measurement;
selecting a starting point on the displayed image;
retrieving the positional data corresponding to said starting point;
selecting an end point on the displayed image;
retrieving the positional data corresponding to said end point; and
calculating the desired measurement dependent at least in part upon said positional data of said starting and end points.

8. The method of claim 7, comprising the further steps of:

selecting one or more intermediate points on said displayed image; and
retrieving the positional data corresponding to said intermediate points.

9. The method of claim 7, wherein said plurality of measurement modes comprise a distance measuring mode calculating a distance between two or more selected points, a height measuring mode calculating a height difference between two or more selected points, a relative elevation measurement mode calculating the difference in elevation of two or more selected points, and an area measurement mode calculating the area encompassed by at least three points.

10. A computerized method for taking measurements within a displayed oblique image, comprising:

selecting with an input device a starting point and an end point on the displayed image; retrieving from a data file positional data corresponding to said starting point and said end point;
referencing a ground plane data file corresponding to a tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said tessellated ground plane closely matching a terrain of said displayed oblique image;
connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and
calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

11. The method of claim 10, wherein said tessellated ground plane is superimposed upon said displayed oblique image.

12. The method of claim 10, comprising the further steps of:

selecting with an input device one or more intermediate points on the displayed image; retrieving from said data file positional data corresponding to said one or more intermediate points; and
connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and
calculating the distance along said line segments between said starting and end points.

13. The method of claim 10, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

14. The method of claim 10, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

15. A computerized method for taking measurements within a displayed oblique image, comprising:

displaying an oblique captured image with positional data;
selecting with an input device two points including a starting point and an end point on the displayed image;
calculating the geo-locations of the selected points in the displayed oblique image based at least in part the upon positional data of the displayed oblique image;
referencing a tessellated ground plane representing at least a portion of the terrain depicted within said captured oblique images, said tessellated ground plane comprising a plurality of interconnected facets, each of said facets having a respective pitch and slope, said tessellated ground plane comprising a plurality of vertices, each vertex having an elevation and defining a corner of a facet, two of said vertices shared by each of said facets;
identifying which of said plurality of facets corresponds to selected points on said displayed oblique image and calculating elevations of said selected points dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point; and
calculating the distance between the selected points.

16. The method of claim 15 comprising the further step of superimposing an image of the upon said displayed oblique image.

17. The method of claim 15, comprising the further steps of:

selecting with an input device one or more intermediate points on the displayed image; retrieving from said data file positional data corresponding to said one or more intermediate points;
connecting adjacent intermediate points to each other;
connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and
calculating the distance along said line segments between said starting and end points.

18. The method of claim 15, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

19. The method of claim 15, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

20. The method of claim 15, comprising the further steps of:

selecting one or more intermediate points on said displayed image; and retrieving the positional data corresponding to said intermediate points.

21. The method of claim 15 wherein the step of calculating distance comprises measuring the different in elevation between two selected points or measuring area defined by at least three points.

22. The method of claim 15 comprising the further steps of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said

method comprising:

subdividing the area of interest into a plurality of sectors;
guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device;
capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective;
guiding the platform along a second path to thereby target said target sectors; capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective;
repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and
recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

23. The method of claim 22, wherein said second path is substantially parallel relative to and 180° from said first path;

24. The method of claim 23, wherein said second path is also spaced apart from said first path.

25. The method of claim 22, comprising the further steps of: guiding the platform along a third path to thereby target one or more target sectors with the image-capturing device, said third path being substantially perpendicular to said first and second paths;

capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a third perspective; and
repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

26. The method of claim 25, comprising the further steps of:

guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180° from said third path;
capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and
repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

27. The method of claim 26, wherein said fourth path is also spaced apart from said third path.

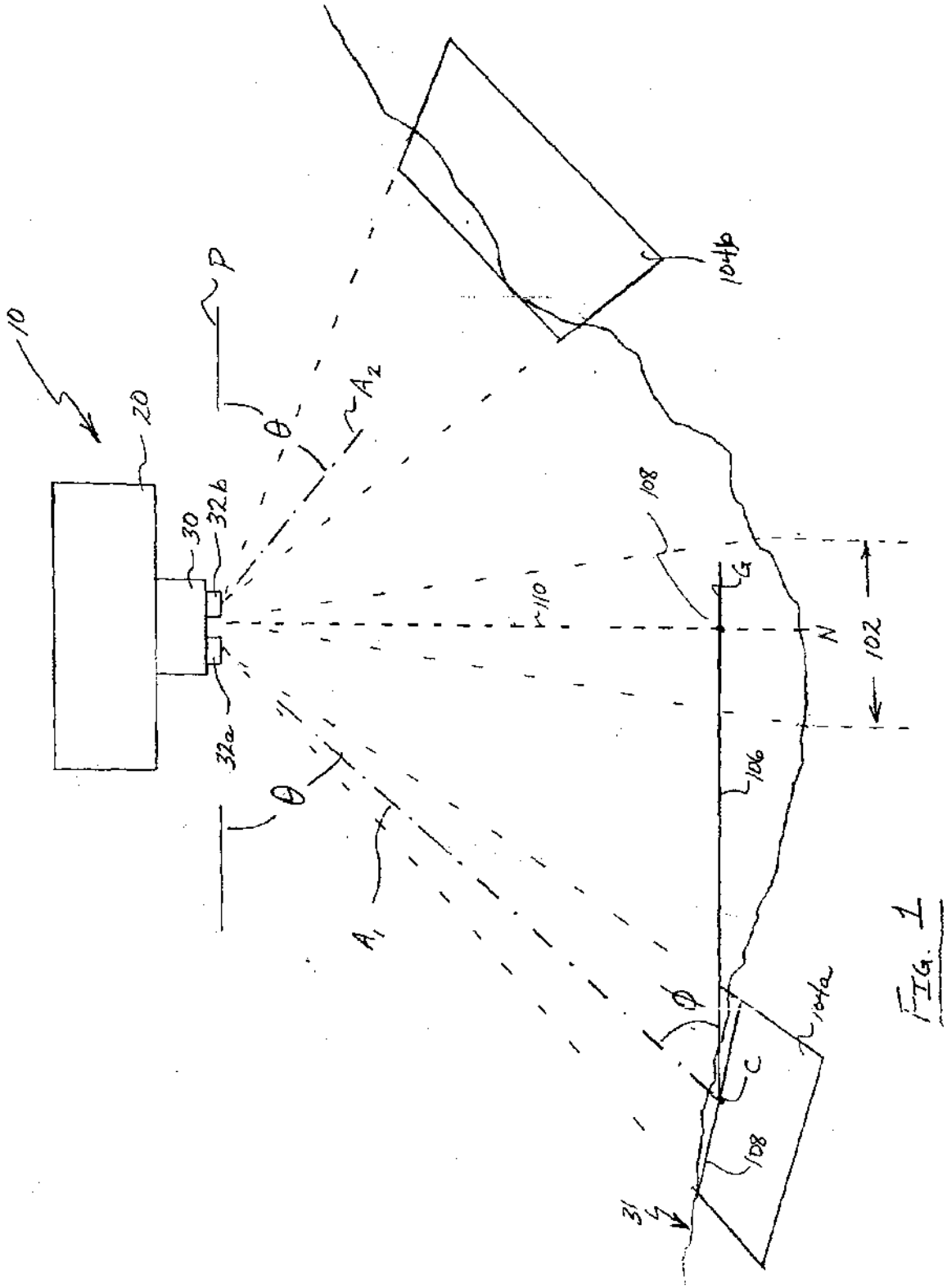


FIG. 1

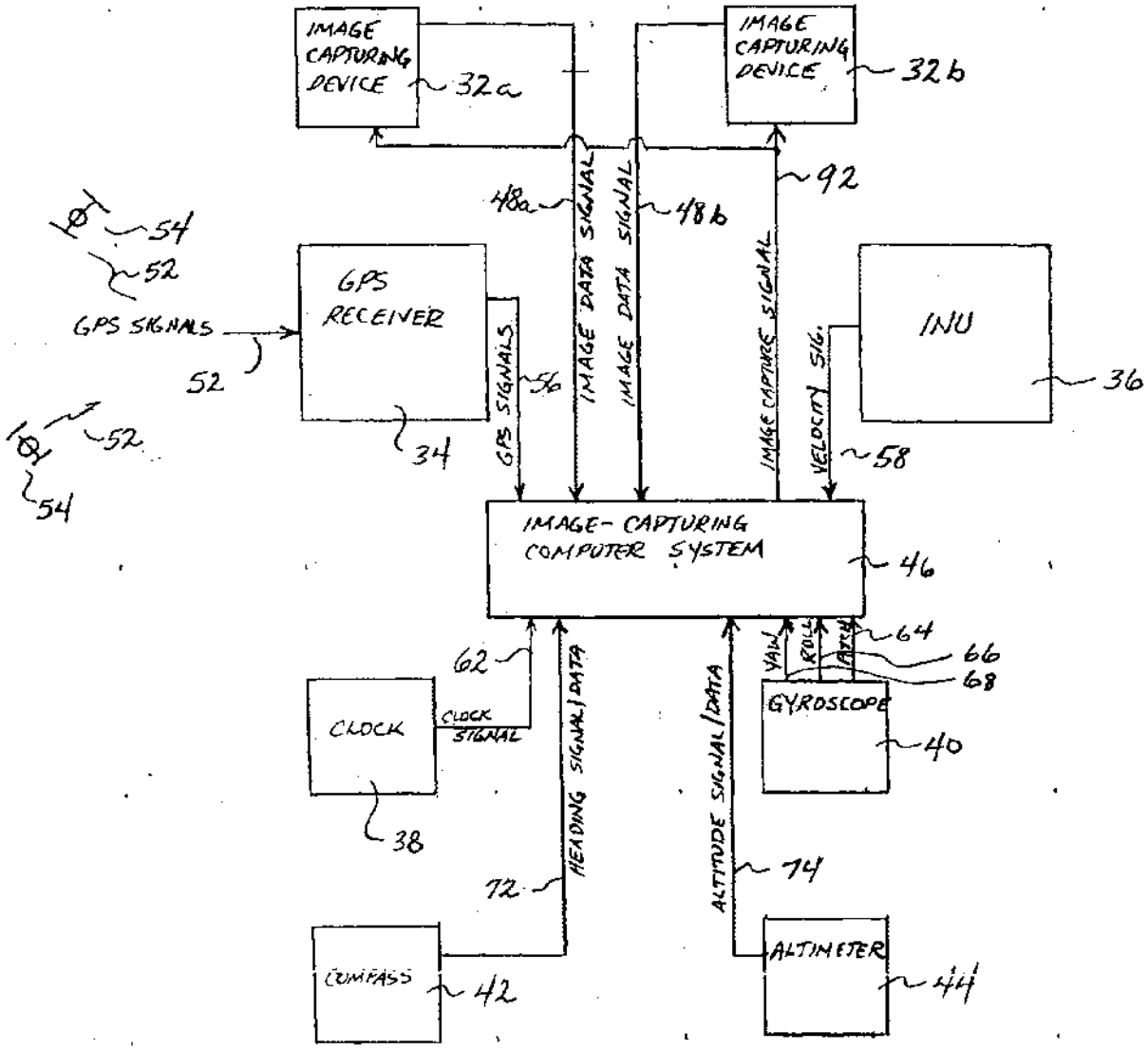

IMAGE CAPTURING DEVICE
32a
IMAGE CAPTURING DEVICE
32b
92
48a
48b
IMAGE DATA SIGNAL
IMAGE DATA SIGNAL
IMAGE CAPTURE SIGNAL
54
52
GPS SIGNALS
52
GPS RECEIVER
34
GPS SIGNALS
56
INU
36
VELOCITY SIG.
58
52
54
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
64
66
68
YAW
ROLL
PITCH
CLOCK
CLOCK SIGNAL
38
GYROSCOPE
40
HEADING SIGNAL/DATA
72
ALTITUDE SIGNAL/DATA
74
COMPASS
42
ALTIMETER
44

FIG. 2

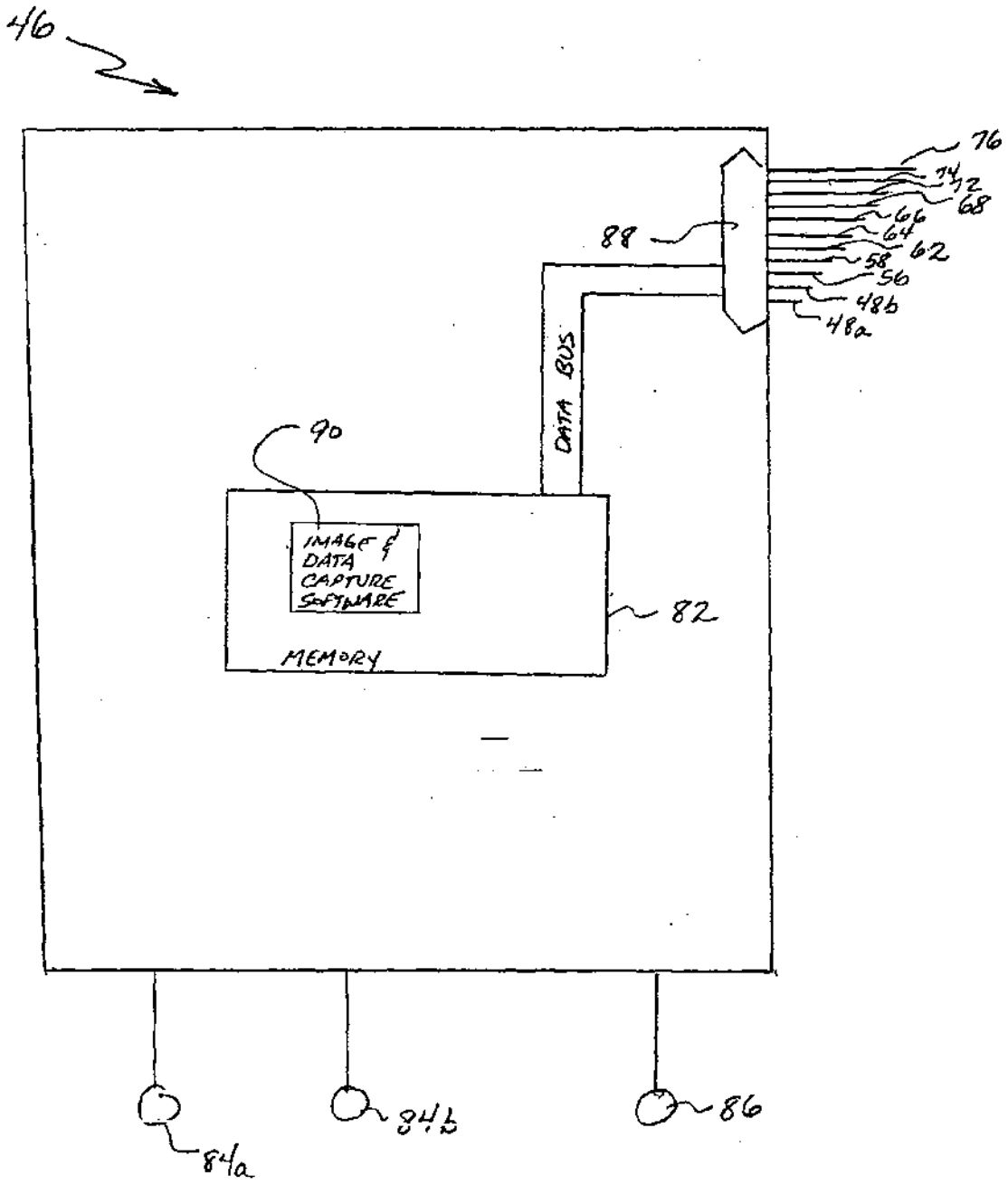

46
76
74
72
68
66
64
62
58
56
48b
48a
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DATA BUS
90
IMAGE & DATA CAPTURE SOFTWARE
MEMORY
82
84a
84b
86

FIG. 3

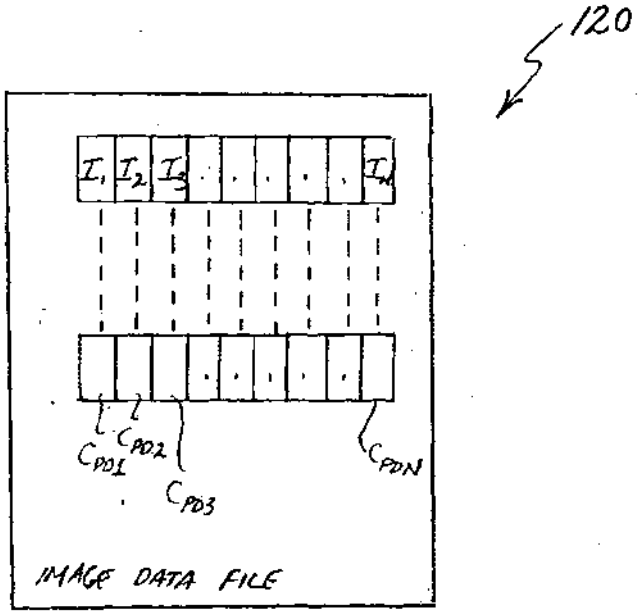


FIG. 4

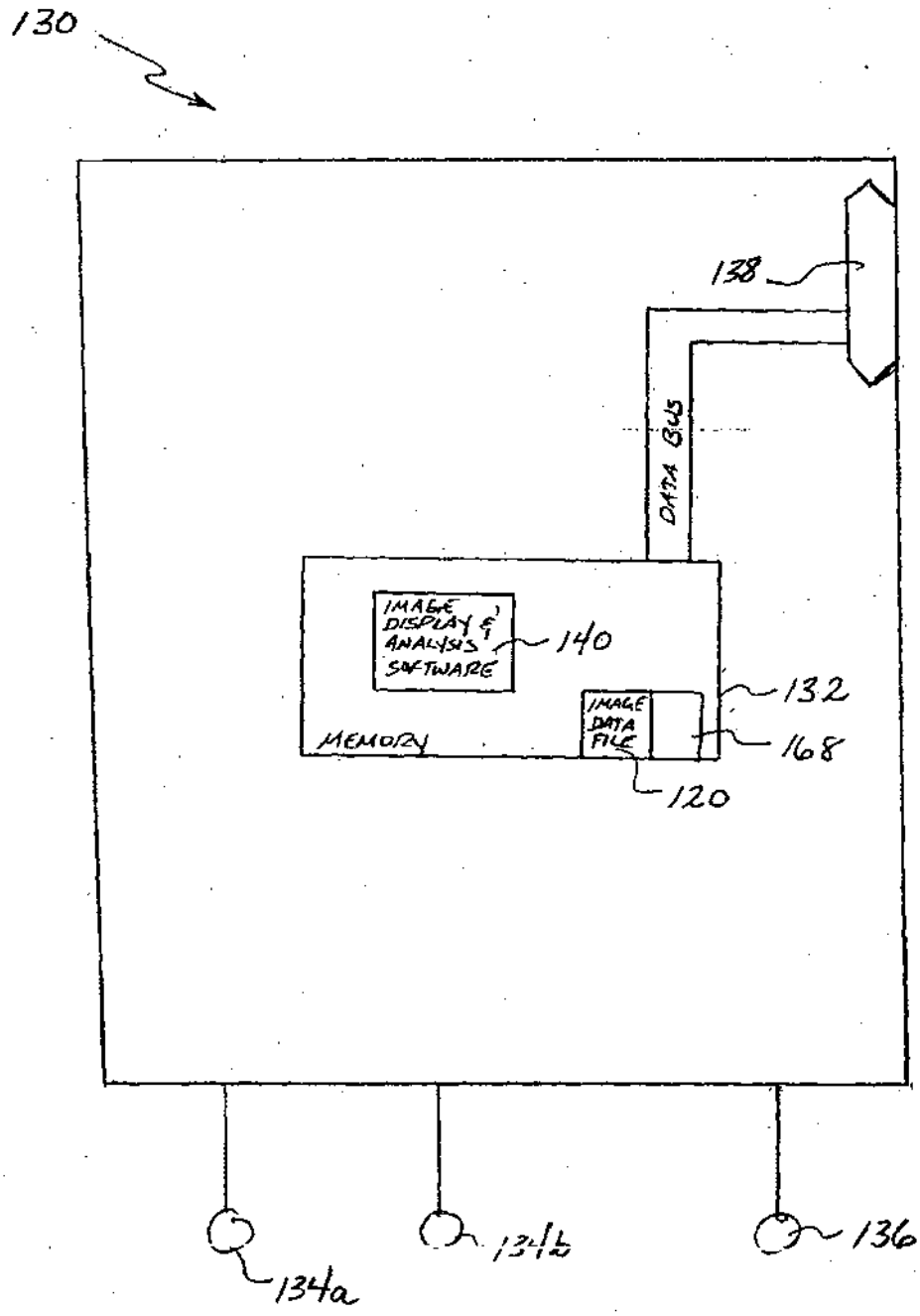

130
138
DATA BUS
IMAGE DISPLAY & ANALYSIS SOFTWARE
140
132
IMAGE DATA FILE
168
MEMORY
120
134a
134b
136

FIG. 5

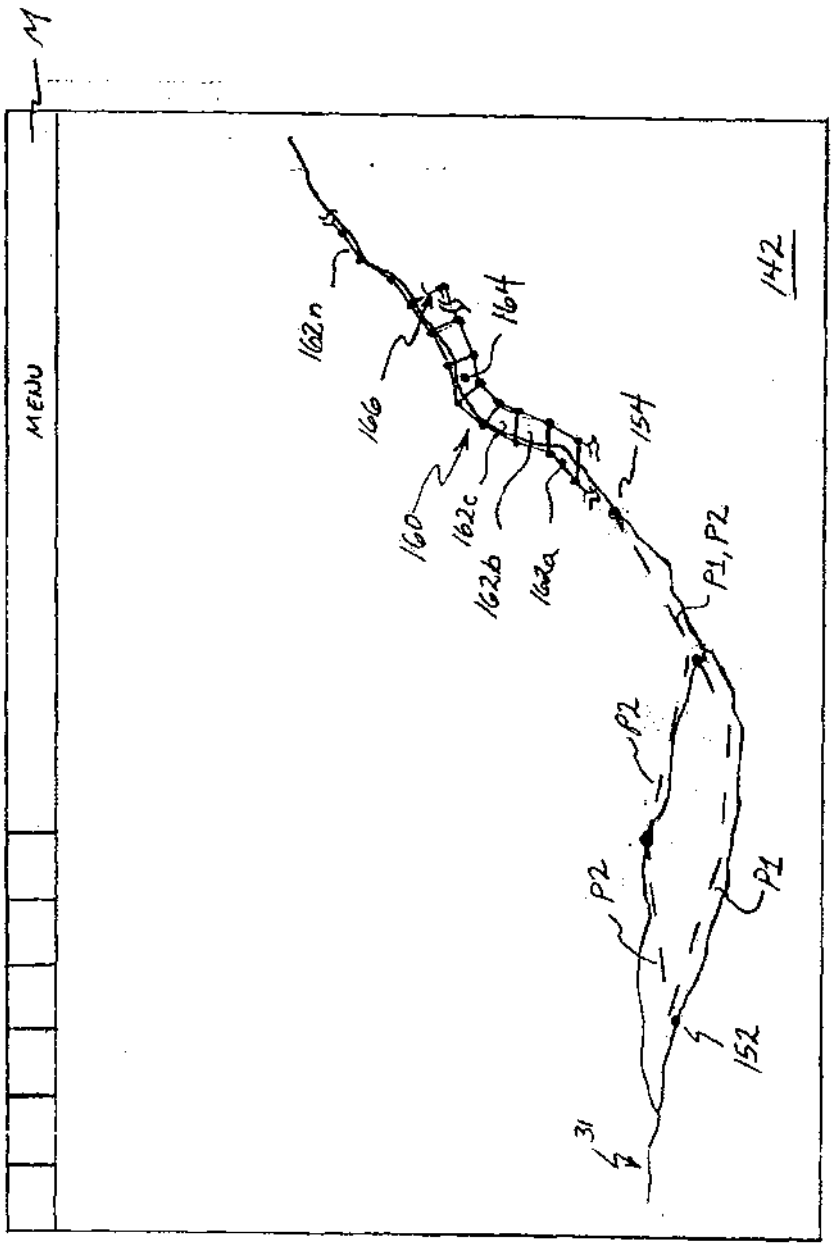

M
MENU
142
162n
164
166
160
162c
162b
162a
154
P1, P2
P2
P2
P1
152
31

FIG. 6

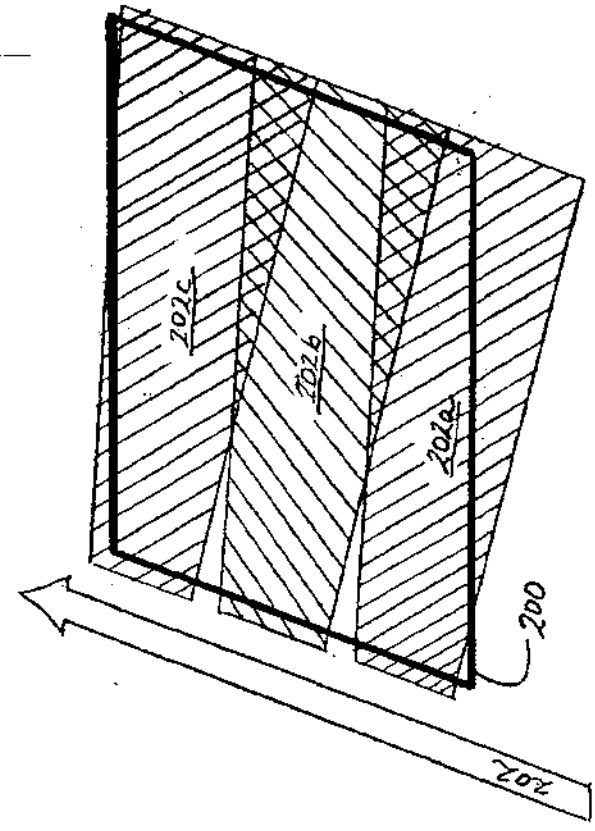


Fig. 1

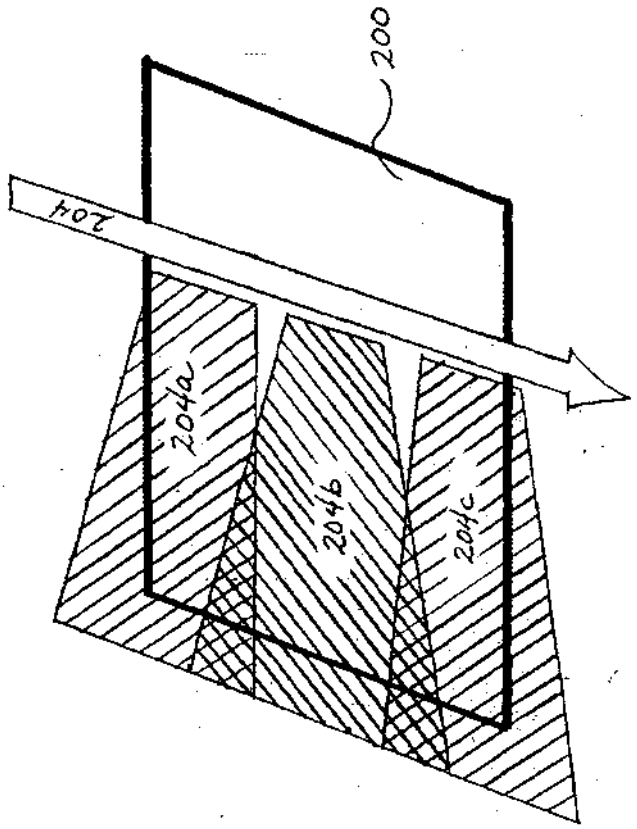


FIG. 8

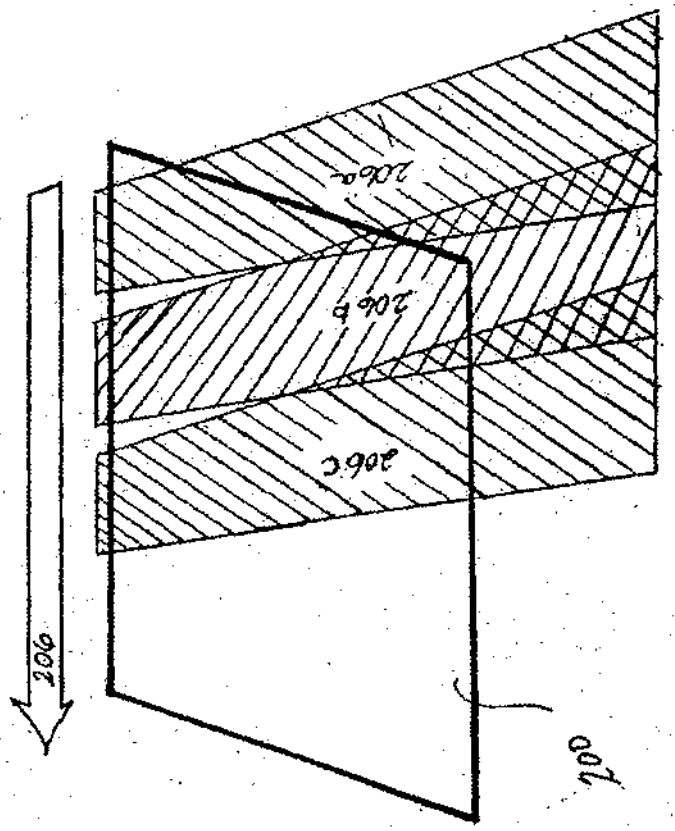


Fig. 9

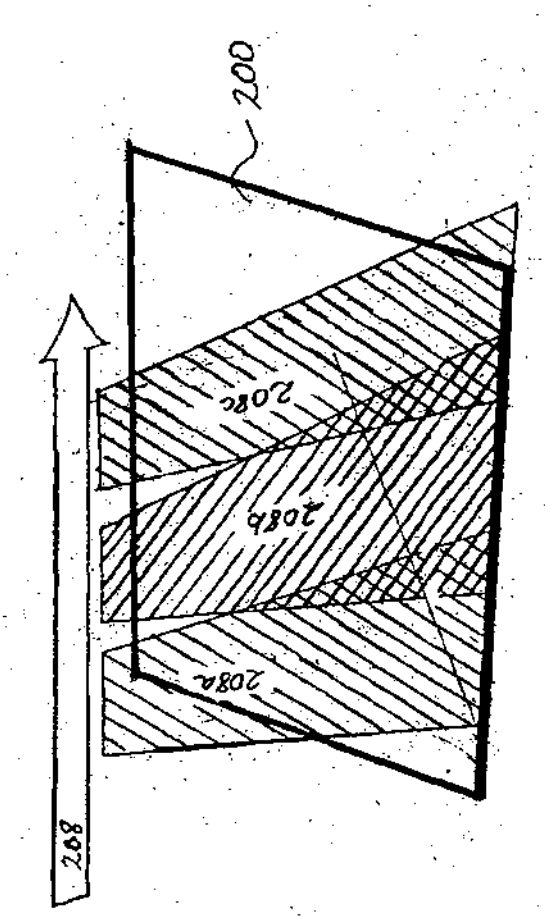


FIG. 10

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CA 2505566 A1 2004/05/27

(21) 2 505 566

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

Roofl Exhibit 1002, Page 411

(86) Date de dépôt PCT/PCT Filing Date: 2003/11/07
(87) Date publication PCT/PCT Publication Date: 2004/05/27
(85) Entrée phase nationale/National Entry: 2005/05/09
(86) N° demande PCT/PCT Application No.: US 2003/035528
(87) N° publication PCT/PCT Publication No.: 2004/044692
(30) Priorité/Priority: 2002/11/08 (60/425,275) US

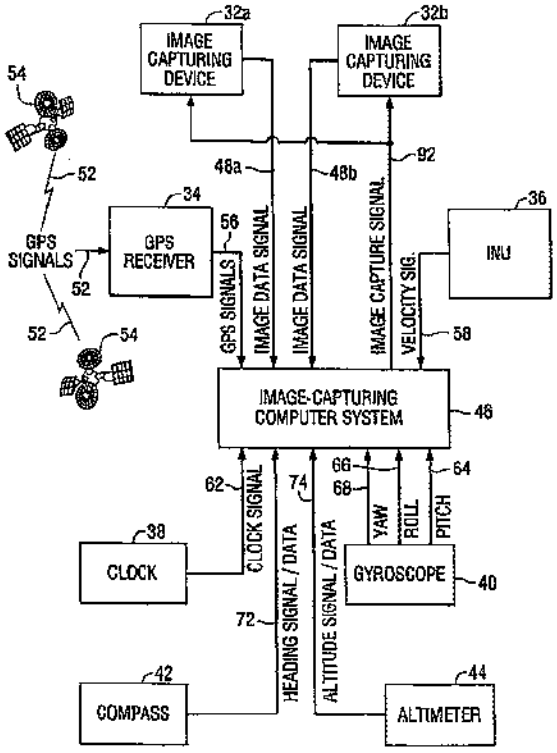
(51) Cl.Int.^{7}/Int.Cl.^{7} G06K 9/40

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(54) Titre : SYSTEME DE LOCALISATION GEOGRAPHIQUE ET DE MESURE A PARTIR D'IMAGES OBLIQUES
(54) Title: OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM



(57) Abrégé/Abstract:
A computerized system (46) for displaying, geolocating, and taking measurements from captured oblique images (32a and 32b) includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images (32a and 32b), and positional data corresponding to the images. Image display and analysis software is executed by the system (46) for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 May 2004 (27.05.2004)

PCT

(10) International Publication Number
WO 2004/044692 A3

(51) International Patent Classification[7]: G06K 9/40

(21) International Application Number:
PCT/US2003/035528

(22) International Filing Date:
7 November 2003 (07.11.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/425,275 8 November 2002 (08.11.2002) US

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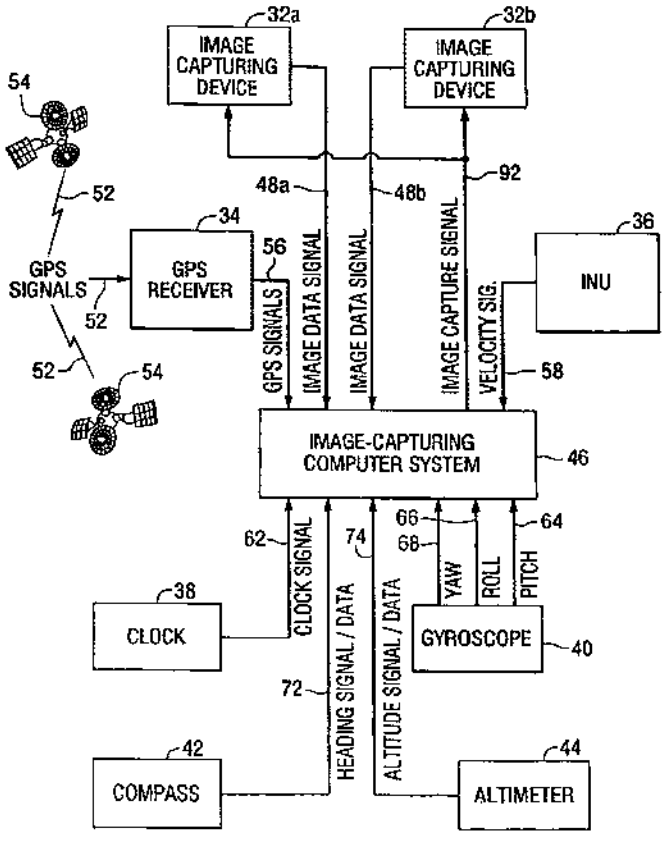
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(81) Designated States *(national)*: AE, AG, AL, AM, AU, AZ, BA, BB, BR, BY, BZ, CA, CN, CO, CR, CU, DK, DM, DZ, EC, EE, ES, FI, GD, GE, GH, GM, HR, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, RU, SC, SD, SG, SL, SY, TJ, TM, TN, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM



(57) Abstract: A computerized system (46) for displaying, geolocating, and taking measurements from captured oblique images (32a and 32b) includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images (32a and 32b), and positional data corresponding to the images. Image display and analysis software is executed by the system (46) for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

WO 2004/044692 A3

WO 2004/044692 A3

Published:

— *with international search report*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(88) Date of publication of the international search report:
22 July 2004

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is

orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or

inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectfified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the

surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which measurements can be made and reducing the accuracy of any such measurements.

Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein.

Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique

images.

Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for capturing, displaying, and making measurements of objects and distances between objects depicted within oblique images.

The present invention comprises, in one form thereof, a computerized system for displaying, geolocating, and taking measurements from captured oblique images. The system includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area

encompassed within, relative elevation of, and height difference between selected points.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby;

FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1;

FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2;

FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1;

FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1;

FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement

of and between objects depicted in such an image;

FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention;

FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-

capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as will be more particularly described hereinafter.

As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A_1 and A_2, and are mounted to platform 20 such that axes A_1 and A_2 are each at an angle of declination ? relative to a horizontal plane *P*. Declination angle ? is virtually any oblique angle, but is preferably from approximately 20° (twenty degrees) to

approximately 60° (sixty degrees) and is most preferably from approximately 40° (forty degrees) to approximately 50° (fifty degrees).

GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and

stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by mage-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer, includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in

memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals

64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

Image and data acquiring software 90 decodes as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the

amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point *N* of orthogonal image 102. Thus, the exact geo-location of the nadir point *N* of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir

point *N* of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination ? of the primary axes A_1 *and* A_2 of image-capturing devices 32a and 32b, respectively.

It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I_1, I_2, . . . , I_n corresponding to captured oblique images, and the positional data C_{PD1}, C_{PD2}, . . .

, C_{PDn} corresponding thereto.

Image files I_1, I_2, . . . , I_n of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} which is also stored as computer-readable data. Alternatively, positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} is embedded within the corresponding image files I_1, I_2, . . . , I_n in known manner. Image data files 120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and

interaction of a user with image display and analysis software 140 being executed by image display and measurement computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images I_1, I_2, . . . , I_n of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or fitted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the

geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars *M*, or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel

154.

When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142

corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 154 which, for simplicity, corresponds to center *C* (Fig. 1) of oblique image 104a. As shown in Fig. 1, line 106 extends along horizontal plane *G* from a point 108 thereon that is directly below image-capturing device 32a to the center *C* of the near border or edge 108 of oblique image 104a. An extension of primary axis A_1 intersects with center *C*. Angle Ø is the angle formed between line 106 the extension of primary axis A_1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center *C*, and having sides 106, the extension of primary axis A_1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

Ground plane *G* is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle Ø and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A_1) and remaining other side of the right triangle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center *C* of oblique image 104a to be determined by image display

and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path *P1* or a path *P2* that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected

therewith.

It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths *P1* and *P2*, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths *P1* and *P2* also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A_1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

For example, if surface 31 slopes upward between nadir point *N* and center *C* at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center *C* is fifteen feet higher than nadir point *N* and with a declination angle ? equal to 40° (forty degrees), the calculated location of center *C* would be off by approximately 17.8 feet without correction for the change in elevation between the points.

As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant inaccuracies in the measurement of and

between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, survey data, and various other sources.

Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc, within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an

area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed above, and that elevation is used within the location calculation.

Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally

uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest – how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an

angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180° (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are

perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a

community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially constant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction

captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary. In fact,

In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180° (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other.

While the present invention has been described as having a preferred design, the invention can be further modified within the spirit and scope of this disclosure. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A system for capturing images and geo-location data corresponding thereto, comprising:

an image-capturing device, said image-capturing device capturing oblique images at image-capturing events, said image capturing device issuing image-data signals corresponding to captured images;

at least one geo-locating device, each said at least one geo-locating device issuing a corresponding at least one geo-locating signal, each said at least one geo-locating signal being indicative at least in part of a geo-location of said image-capturing device during each image capturing event; and

a computer system receiving and storing said image-data signals and said at least one geo-locating signal; and

image and data acquiring software reading said image-data signals and said at least one geo-locating signal, said software associating each said image-data signal with a corresponding said at least one geo-locating signal for each image-capturing event.

2. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise at least one of:

a clock issuing to said image-capturing computer system time data signals

indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

3. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise:

a clock issuing to said image-capturing computer system time data signals indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

4. The system of claim 1, further comprising correction data indicative of characteristics of said image-capturing device including focal length, sensor size, radial distortion, principal point offset and alignment, said image and data acquiring software utilizing said correction data to correct captured images.

5. The system of claim 1, further comprising an output data file created by said image and data acquiring software, said output data file including a plurality of image files and positional data corresponding to each of said plurality of image files.

6. The system of claim 1, further comprising a platform carrying said image-capturing device a predetermined distance above a surface of interest.

7. A computerized system for displaying, geolocating, and making measurements based upon captured oblique images, comprising:

a computer system having a memory;

an image and data file accessible by said system and including a plurality of image files corresponding to a plurality of captured oblique images, said image and data file further including positional data corresponding to said plurality of image files;

image display and analysis software executed by said system for reading said image and data file and displaying at least a portion of the captured oblique images as a displayed image, said software retrieving said positional data of one or more selected points within said displayed image, said software calculating a separation distance between any two or more selected points within said displayed image.

8. The system of claim 7, further comprising a ground plane data file representing a tessellated ground plane, said ground plane data file accessible by said

computer system, said ground plane data file representing a tessellated ground plane that closely approximates at least a portion of the terrain depicted within said captured oblique images.

9. The system of claim 8, wherein said tessellated ground plane further comprises a plurality of interconnected facets, each of said plurality of facets having a respective pitch and slope.

10. The system of claim 9, wherein said ground plane data file comprises a plurality of vertices, each of said plurality of vertices having respective elevations and defining corners of said plurality of interconnected facets, two of said plurality of vertices shared by each of said interconnected facets.

11. The system of claim 10, wherein said image display and analysis software identifies which of said plurality of facets corresponds to a selected point on said displayed image, and calculates an elevation of said selected point dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point, said image display and analysis software using said calculated elevation for calculating said separation distance between said selected point and one or more further selected points.

12. The system of claim 11, wherein said image display and analysis software calculates a height of an object within said displayed image by calculating the separation distance between two or more selected points.

13. The system of claim 8, wherein said tessellated ground plane is one of superimposed upon and fit to said displayed image.

14. The system of claim 7, wherein said image display and analysis software includes user-selectable measuring modes accessible through at least one of pull-down menus, toolbars and keyboard commands.

15. The system of claim 7, wherein each of said images were captured by an image-capturing device and at respective image capturing events, said positional data of said image and data file including:

time data representing the time of each image-capturing event;

location data representing the location of the image-capturing device at each image-capturing event;

orientation data representing the orientation of the image-capturing device at each image-capturing event;

correction data representing correction factors for the image-capturing device; and

elevation data representing an average elevation of the surface captured by the image-capturing device.

16. The system of claim 15, wherein said location data includes latitude, longitude, and altitude of the image-capturing apparatus at each image-capturing event.

17. The system of claim 15, wherein said orientation data includes roll, pitch, yaw and heading of said image-capturing device at each image-capturing event.

18. The data set of claim 15, wherein said image-capturing device is a camera and said correction data includes at least one of focal length, sensor size, aspect ratio, principle point offset, distortion, and pixel pitch.

19. A computerized method for taking measurements within a displayed oblique image, comprising:

selecting with an input device a starting point and an end point on the displayed image;

retrieving from a data file positional data corresponding to said starting point and said end point;

referencing a ground plane data file corresponding to a tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said

tessellated ground plane closely matching a terrain of said displayed oblique image;

connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

20. The method of claim 19, wherein said tessellated ground plane is superimposed upon said displayed oblique image.

21. The method of claim 19, comprising the further steps of:

selecting with an input device one or more intermediate points on the displayed image;

retrieving from said data file positional data corresponding to said one or more intermediate points; and

connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the distance along said line segments between said starting and end points.

22. The method of claim 19, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

23. The method of claim 19, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

24. A computerized method for taking measurements from an oblique image displayed on a computer system, at least one input device connected to said computer system, an image data file accessible by said computer system, said image data file including captured images and positional data corresponding thereto, said computerized method comprising:

placing the computer system into a desired one of a plurality of measurement modes, the desired measurement mode configured for calculating a desired measurement;

selecting a starting point on the displayed image;

retrieving the positional data corresponding to said starting point;

selecting an end point on the displayed image;

retrieving the positional data corresponding to said end point; and

calculating the desired measurement dependent at least in part upon said positional data of said starting and end points.

25. The method of claim 24, comprising the further steps of:

selecting one or more intermediate points on said displayed image; and

retrieving the positional data corresponding to said intermediate points.

26. The method of claim 24, wherein said plurality of measurement modes comprise a distance measuring mode calculating a distance between two or more selected points, a height measuring mode calculating a height difference between two or more selected points, a relative elevation measurement mode calculating the difference in elevation of two or more selected points, and an area measurement mode calculating the area encompassed by at least three points.

27. A method of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said method comprising:

subdividing the area of interest into a plurality of sectors;

guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective;

guiding the platform along a second path to thereby target said target sectors;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective;

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and

recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

28. The method of claim 27, wherein said second path is substantially parallel relative to and 180° (one-hundred and eighty degrees) from said first path;

29. The method of claim 28, wherein said second path is also spaced apart from said first path.

30. The method of claim 27, comprising the further steps of:

guiding the platform along a third path to thereby target one or more target sectors with the image-capturing device, said third path being substantially perpendicular to said first and second paths;

capturing with the image-capturing device one or more oblique images to thereby

capture an entirety of each said target sector in oblique images captured from a third perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

31. The method of claim 30, comprising the further steps of:

guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180° (one-hundred and eighty degrees) from said third path;

capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

32. The method of claim 31, wherein said fourth path is also spaced apart from said third path.

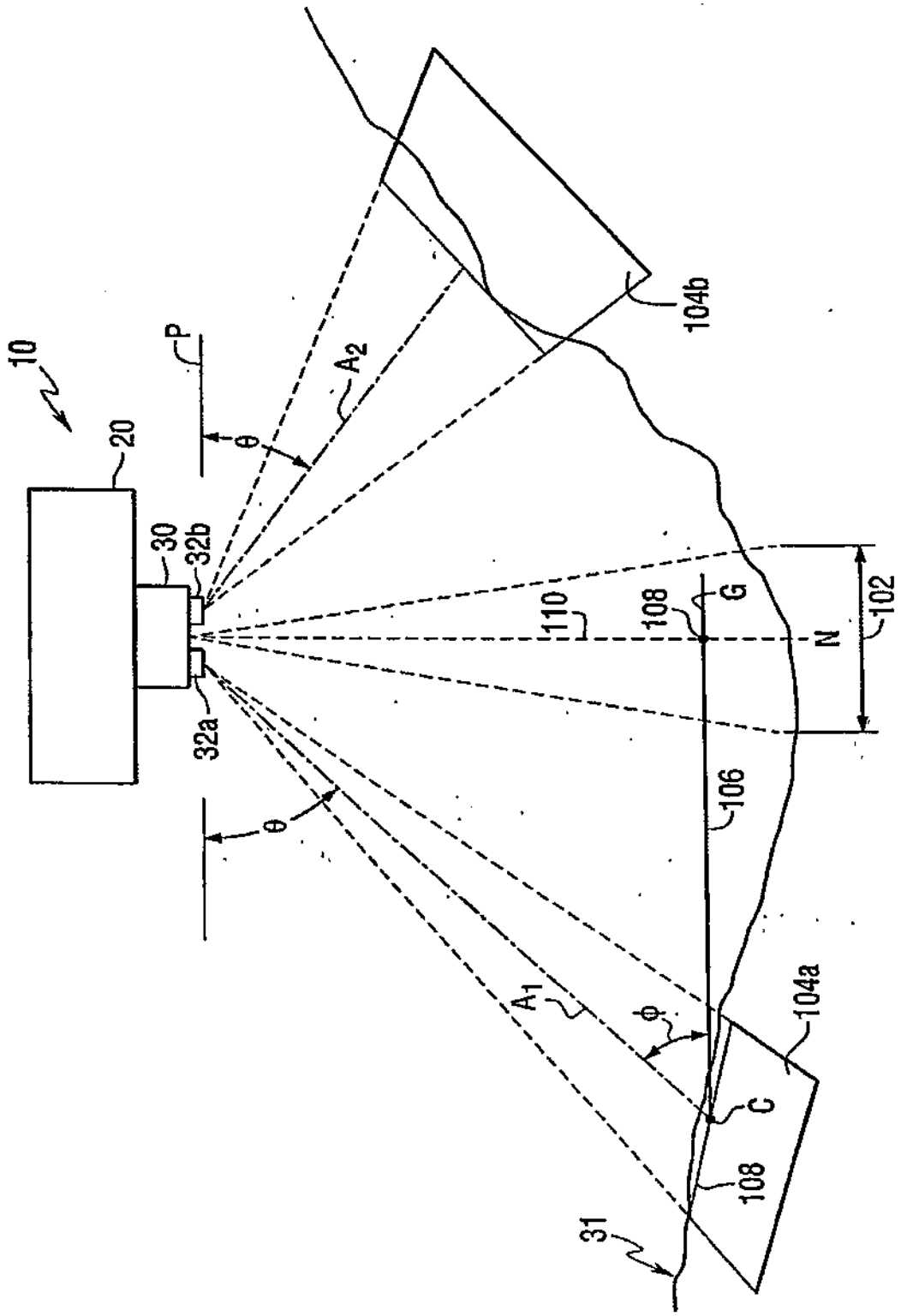


FIG. 1

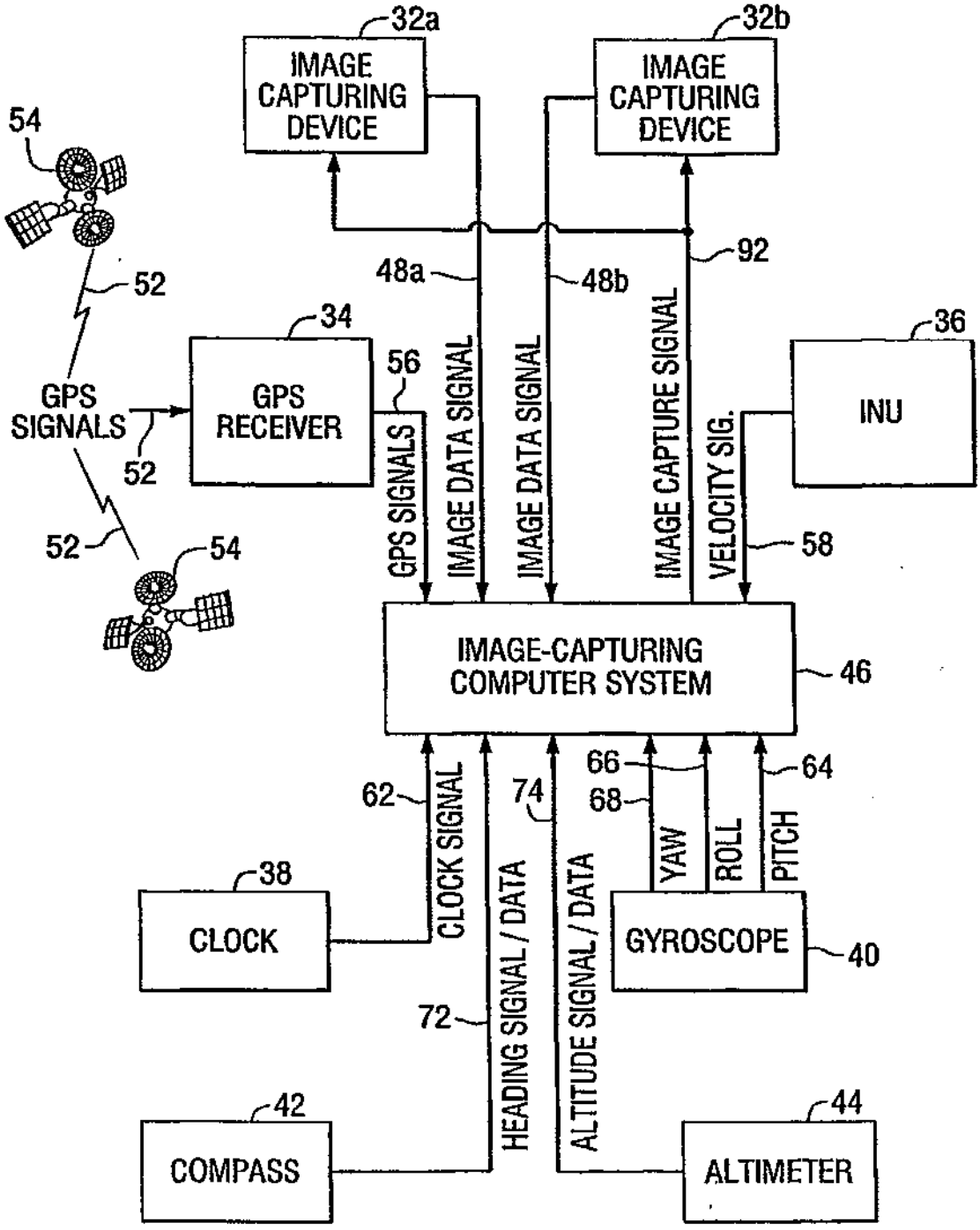

32a
IMAGE CAPTURING DEVICE
32b
IMAGE CAPTURING DEVICE
54
52
48a
48b
92
34
GPS SIGNALS
52
GPS RECEIVER
56
GPS SIGNALS
IMAGE DATA SIGNAL
IMAGE DATA SIGNAL
IMAGE CAPTURE SIGNAL
VELOCITY SIG.
36
INU
58
52
54
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
CLOCK SIGNAL
74
HEADING SIGNAL / DATA
ALTITUDE SIGNAL / DATA
66
68
YAW
ROLL
PITCH
64
38
CLOCK
GYROSCOPE
40
72
42
COMPASS
44
ALTIMETER

FIG. 2

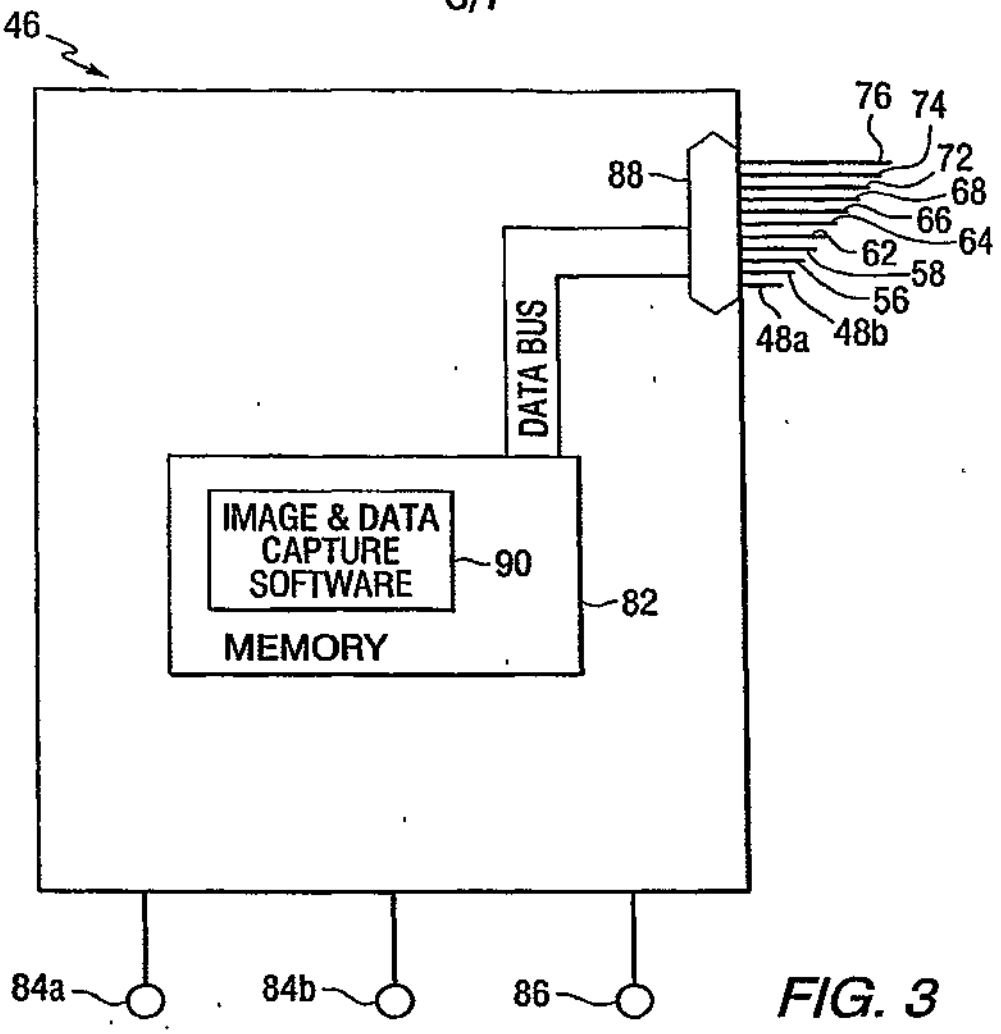

46
76
74
72
68
66
64
62
58
56
88
48a
48b
DATA BUS
IMAGE & DATA CAPTURE SOFTWARE
90
82
MEMORY
84a
84b
86

FIG. 3

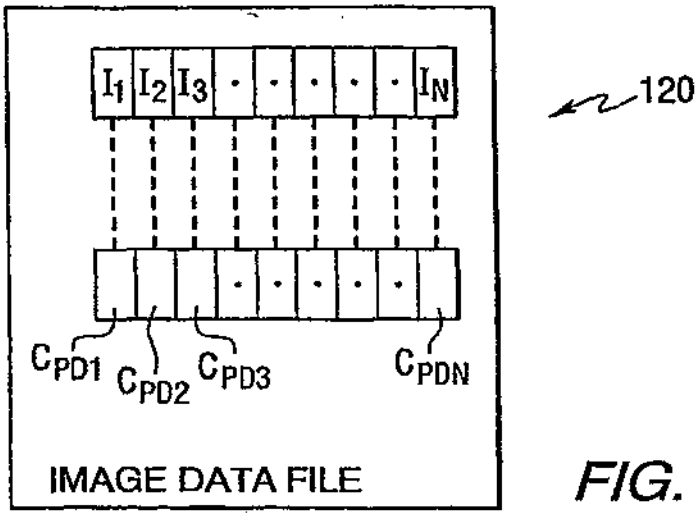

I_1 I_2 I_3 · · · · · I_N
120
C_{PD1} C_{PD2} C_{PD3} C_{PDN}
IMAGE DATA FILE

FIG. 4

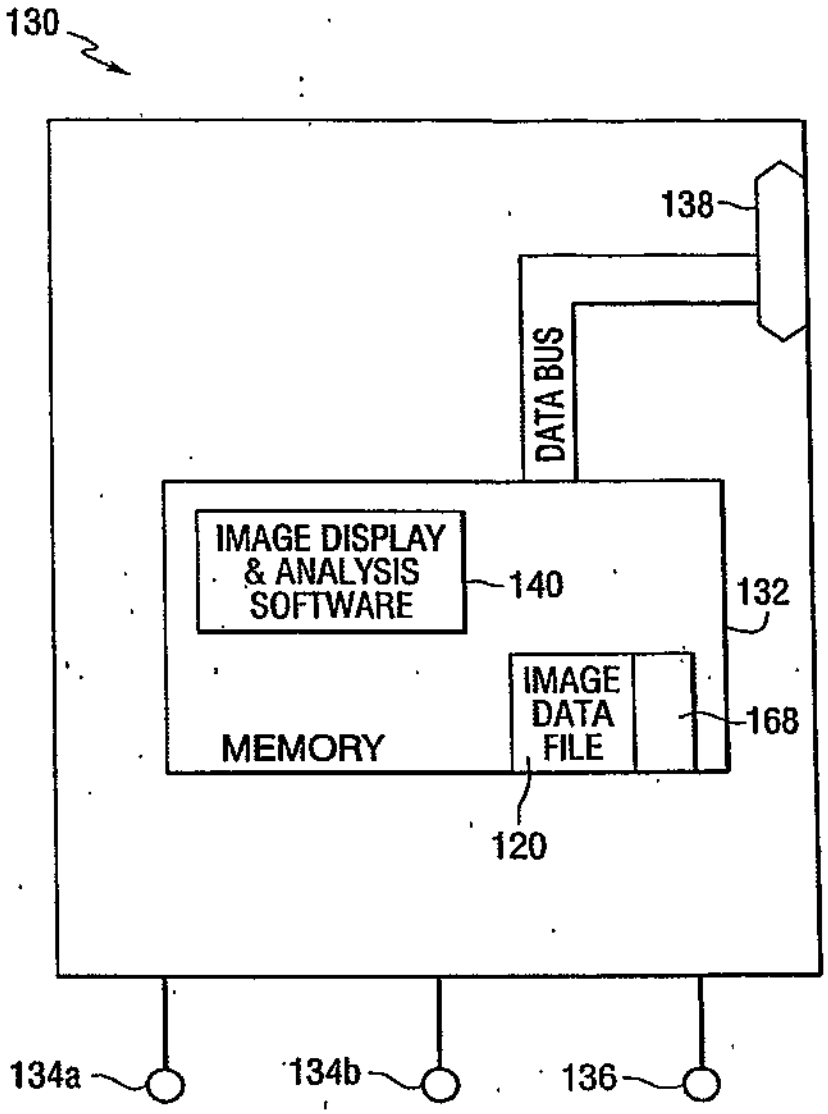

130
138
DATA BUS
IMAGE DISPLAY & ANALYSIS SOFTWARE
140
132
IMAGE DATA FILE
168
MEMORY
120
134a
134b
136

FIG. 5

5/7

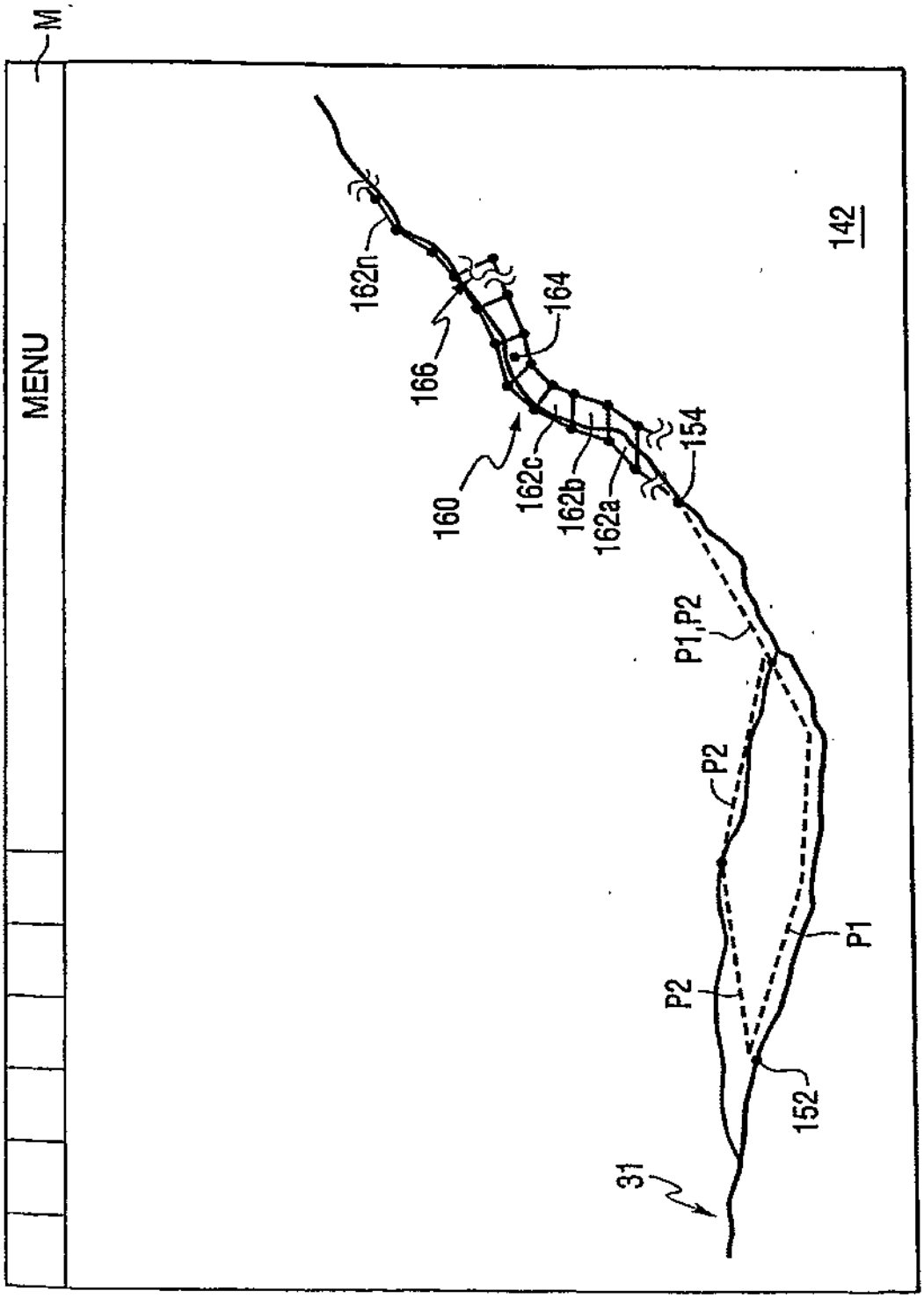

M
MENU
142
162n
164
166
160
162c
162b
162a
154
P1,P2
P2
P1
P2
152
31

FIG. 6

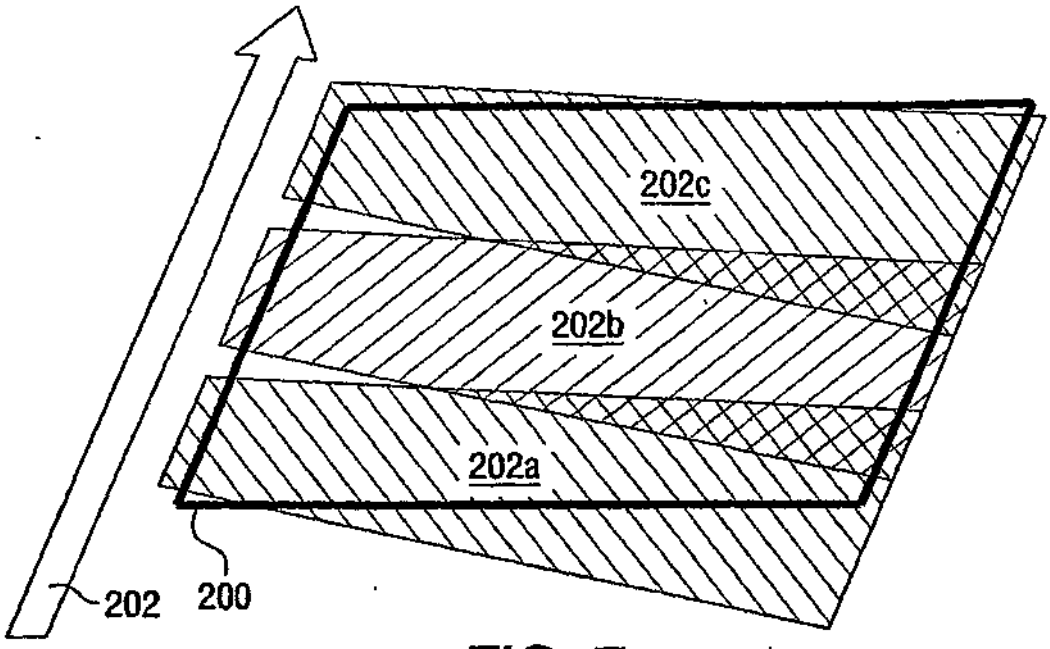


FIG. 7

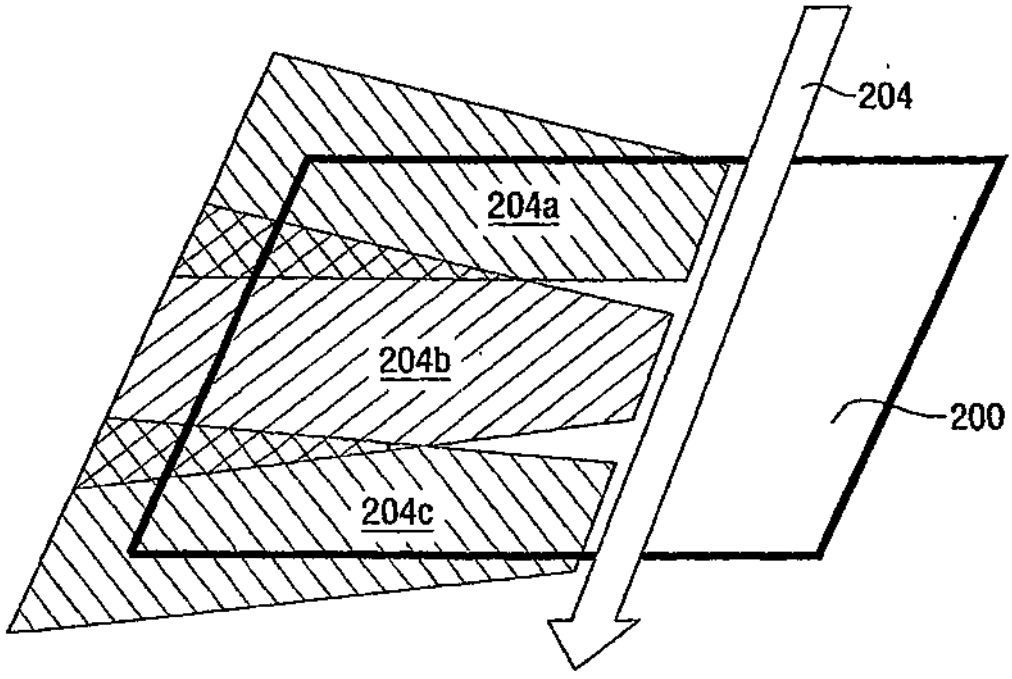


FIG. 8

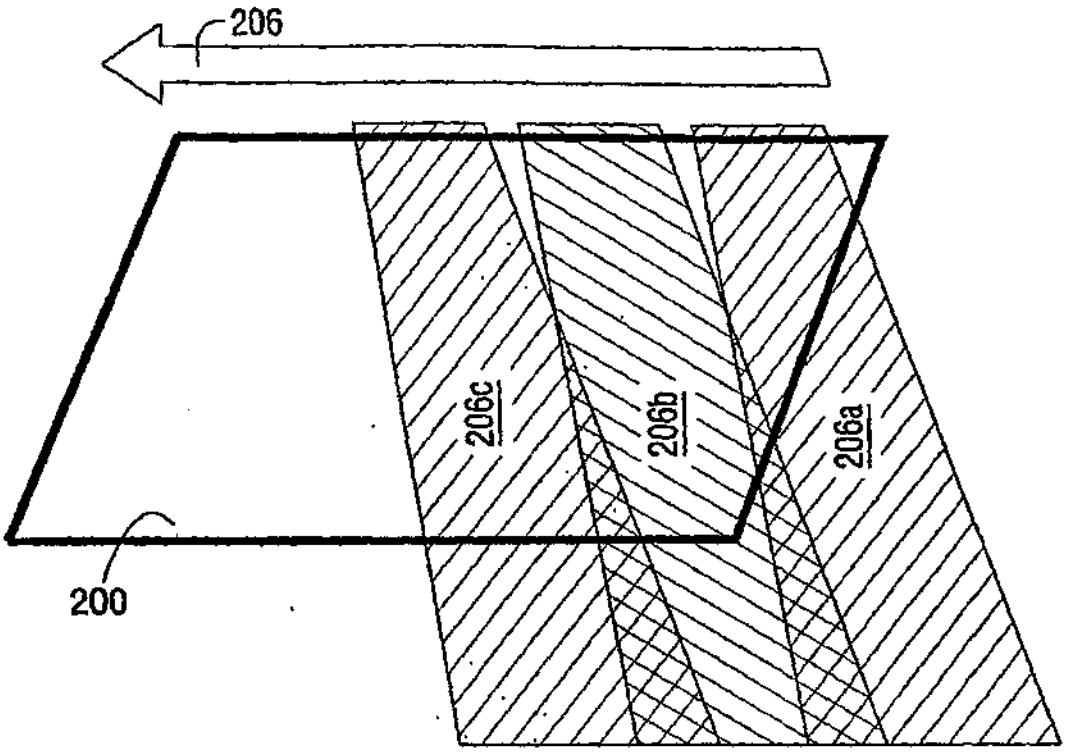


FIG. 9

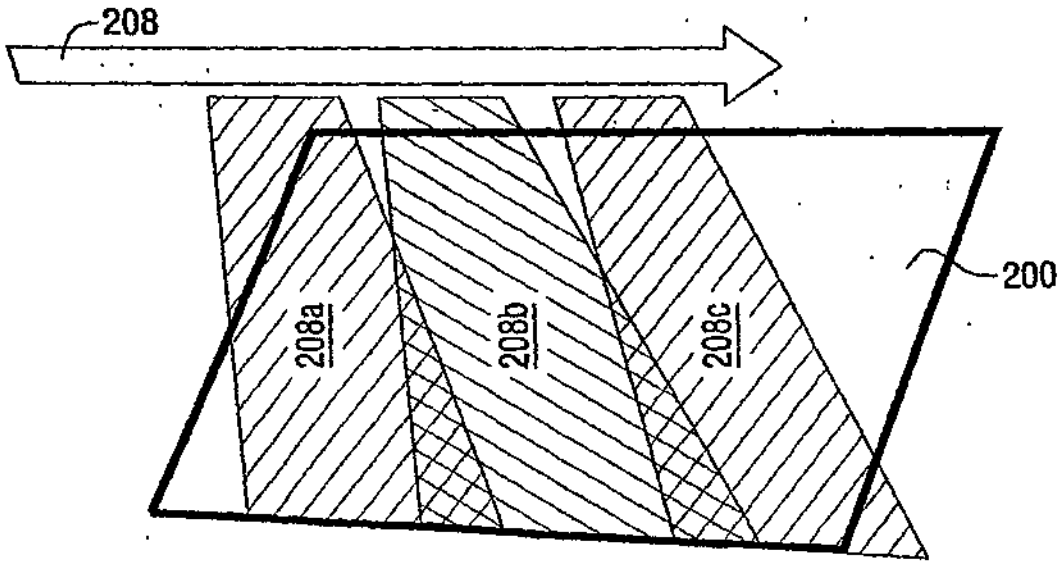
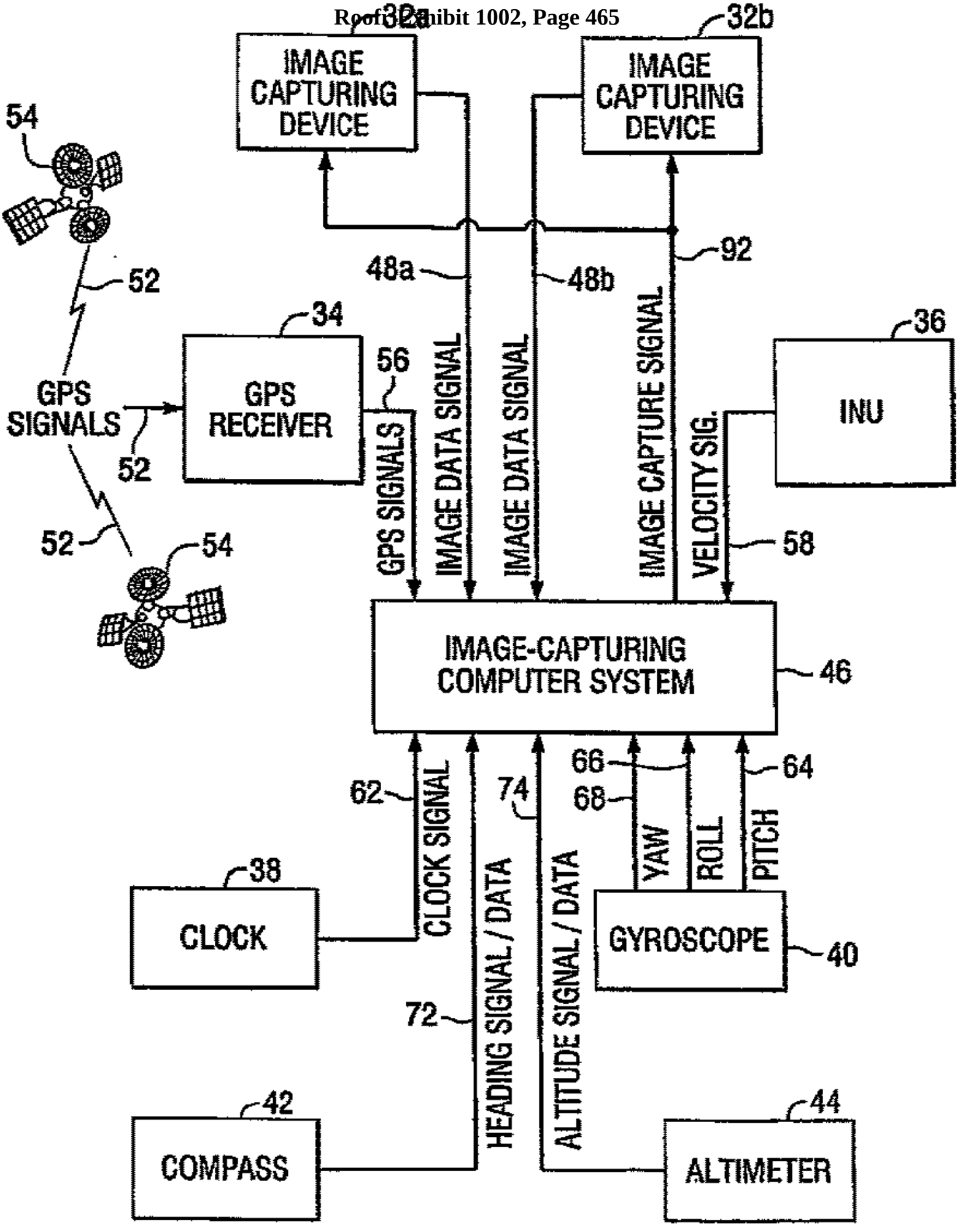


FIG. 10


32a
IMAGE CAPTURING DEVICE
32b
IMAGE CAPTURING DEVICE
54
52
GPS SIGNALS
52
34
GPS RECEIVER
56
GPS SIGNALS
48a
IMAGE DATA SIGNAL
48b
IMAGE DATA SIGNAL
92
IMAGE CAPTURE SIGNAL
36
INU
VELOCITY SIG.
58
52
54
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
CLOCK SIGNAL
74
HEADING SIGNAL / DATA
ALTITUDE SIGNAL / DATA
66
68
YAW
ROLL
PITCH
64
38
CLOCK
GYROSCOPE
40
72
42
COMPASS
44
ALTIMETER

Instituto Mexicano de la Propiedad Industrial

(11) **MX PA05004987 A**

(12) **SOLICITUD de PATENTE**

(43) Fecha de publicación: **17/02/2006**

(51) Int. Cl.: **G06F 00/00**, G06K 09/40

(22) Fecha de presentación: **09/05/2005**
(21) Número de solicitud: **PA05004987**

(86) Número de solicitud PCT: **US 03/35528**
(87) Número de publicación PCT: **WO 2004/044692 (27/05/2004)**

(30) Prioridad(es): **08/11/2002 US 60/425,275**

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(54) Titulo: **GEOLOCALIZACION OBLICUA Y SISTEMA DE MEDICION.**
(54) Title: **OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM.**

(57) Resumen

Un sistema computarizado para visualizar, geolocalizar, y hacer mediciones de imagenes oblicuas capturadas incluye un archivo de datos accesible por medio del sistema de computo. El archivo de datos incluye una pluralidad de archivos de imagenes que corresponden a una pluralidad de imagenes oblicuas capturadas, y datos de posicion que corresponden a las imagenes. Se ejecuta un software de visualizacion y analisis de imagenes a traves del sistema para leer los archivos de datos y visualizar al menos una parte de las imagenes oblicuas capturadas. El software recupera los datos de posicion para uno o mas puntos seleccionados por el usuario en la imagen visualizada, y calcula una distancia de separacion entre cualquiera de dos o mas puntos elegidos. El calculo de la distancia de separacion la selecciona el usuario para determinar varios parametros incluyendo la distancia lineal, area abarcada, elevacion relativa, y diferencia de altura entre puntos seleccionados.

(57) Abstract

A computerized system (46) for displaying, geolocating, and taking measurements from captured oblique images (32a and 32b) includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images (32a and 32b), and positional data corresponding to the images. Image display and analysis software is executed by the system (46) for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between. area encompassed within, relative elevation of, and height difference between selected points.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 May 2004 (27.05.2004)

PCT

(10) International Publication Number
WO 2004/044692 A2

(51) International Patent Classification[7]: G06F

(21) International Application Number:
PCT/US2003/035528

(22) International Filing Date:
7 November 2003 (07.11.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/425,275 8 November 2002 (08.11.2002) US

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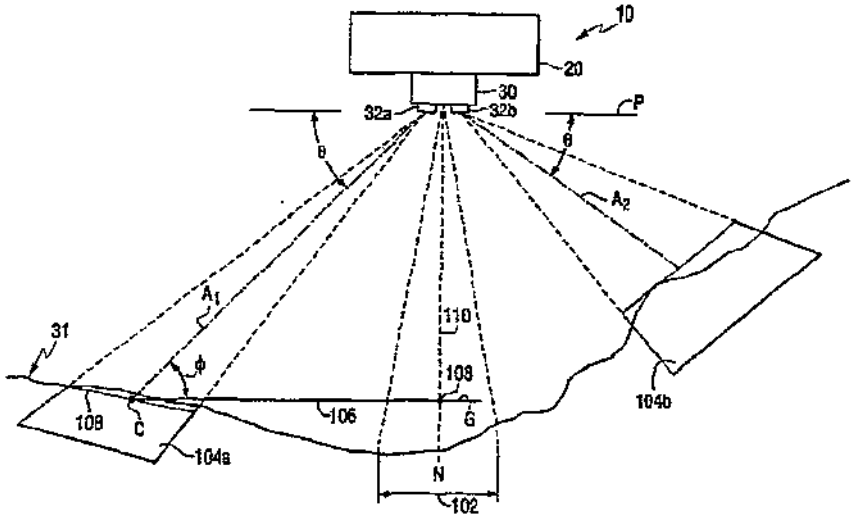
(81) Designated States (*national*): AE, AG, AL, AM, AU, AZ, BA, BB, BR, BY, BZ, CA, CN, CO, CR, CU, DK, DM, DZ, EC, EE, ES, FI, GD, GE, GH, GM, HR, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, RU, SC, SD, SG, SL, SY, TJ, TM, TN, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM



(57) Abstract: A computerized system for displaying, geolocating, and taking measurements from captured oblique images includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

WO 2004/044692 A2

GEOLOCALIZACION OBLICUA Y SISTEMA DE MEDICION

CAMPO DE LA INVENCIÓN

La presente invención se relaciona con la fotogrametría. Más en particular, la presente invención se relaciona con un método y aparato para capturar imágenes oblicuas y para medir los objetos y distancias entre los objetos representados en las mismas.

ANTECEDENTES DE LA INVENCIÓN

La fotogrametría es la ciencia de hacer mediciones de objetos y entre los mismos, representados en fotografías, especialmente fotografías aéreas. Generalmente, la fotogrametría involucra tomar imágenes de características terrestres y derivar datos de las mismas, tales como, por ejemplo, datos que indican las distancias relativas entre objetos y tamaños de los mismos en las imágenes. La fotogrametría puede involucrar también juntar las fotografías con otros datos, tales como datos representativos de latitud y longitud. En efecto, la imagen se superpone y se conforma a un sistema coordenado espacial particular.

La fotogrametría convencional involucra la captura y/o adquisición de imágenes ortogonales. El dispositivo de captura de imágenes, tal como un cámara o sensor, es llevado por un vehículo o plataforma, tal como un aeroplano o satélite, y es dirigido a un punto nadir que está

directamente debajo y/o verticalmente hacia abajo de la plataforma. El punto o píxel en la imagen que corresponde al punto nadir es el único punto/píxel que es verdaderamente ortogonal al dispositivo de captura de imágenes. Todos los demás puntos o píxeles en la imagen son en realidad oblicuos en relación al dispositivo de captura de imágenes. Al alejarse cada vez más los puntos o pixeles del punto nadir se hacen cada vez más oblicuos en relación con el dispositivo de captura de imágenes y la distancia de la muestra del suelo (es decir, el área superficial que corresponde o que está cubierta por cada píxel) también aumenta. Tales oblicuidad en una imagen ortogonal ocasiona que las características en la imagen se distorsionen, especialmente imágenes relativamente alejadas del punto nadir.

Tal distorsión es removida, o compensada, por el proceso de ortorrectificación el cual, en esencia, remueve la oblicuidad de la imagen ortogonal ajustando o combando cada píxel de una imagen ortogonal en una rejilla ortométrica o sistema coordenado. El proceso de la ortorrectificación crea una imagen en donde todos los píxeles tienen la misma distancia de muestra de suelo y están orientados hacia el norte. Por lo tanto, cualquier punto en una imagen ortorrectificada se puede localizar usando un sistema coordenado X, Y y, tan pronto como se conoce la escala de la

imagen, se puede calcular la longitud y anchura de las características terrestres así como la distancia relativa entre esas características.

A pesar de que el proceso de ortorrectificación compensa hasta cierto grado distorsiones oblicuas en una imagen ortogonal, introduce otras distorsiones indeseables y/o imprecisiones en la imagen ortogonal ortorrectificada. Los objetos representados en las imágenes ortogonales ortorrectificadas pueden ser difíciles de reconocer y/o identificar dado que la mayoría de los observadores no están acostumbrados a ver objetos, particularmente características terrestres, desde arriba. Para un observador sin entrenamiento una imagen ortorrectificada tiene un número de distorsiones. Los caminos que en realidad son rectos parecen curvados y los edificios puede parecer inclinados. Además, las imágenes ortorrectificadas no contienen substancialmente información con respecto a la altura de las características terrestres. La interpretación y análisis de imágenes ortogonales y/u ortogonales ortorrectificadas la realizan típicamente analistas altamente entrenados quienes se han sometido a años de entrenamiento y experiencia con el objeto de identificar objetos y características terrestres en tales imágenes.

Por lo tanto, a pesar de que las imágenes ortogonales y ortorrectificadas son útiles en fotogrametría, carecen de

información acerca de la altura de las características ilustradas en las mismas y requieren analistas altamente entrenados para interpretar detalles de lo que la imagen representa.

Las imágenes oblicuas son imágenes que son capturadas con el dispositivo de captura de imágenes dirigido o apuntado generalmente al lado y hacia debajo de la plataforma que lleva el dispositivo de captura de imágenes. Las imágenes oblicuas, a diferencia de las imágenes ortogonales, muestran los lados de características terrestres, tales como casas, edificios y/o montañas, así como las partes superiores de las mismas. Por lo tanto, ver una imagen oblicua es más natural e intuitivo que ver una imagen ortogonal u ortorrectificada, y aún los observadores casuales son capaces de reconocer e interpretar características terrestres y otros objetos representados en imágenes oblicuas. Cada píxel en el primer plano de una imagen oblicua corresponde a un área relativamente pequeña de la superficie u objeto representado (es decir, cada píxel de primer plano tiene una distancia de muestra del suelo relativamente pequeña) mientras que cada píxel en el fondo corresponde a un área relativamente grande de la superficie u objeto ilustrado (es decir, cada píxel del fondo tiene una distancia de muestra del suelo relativamente grande). Las imágenes oblicuas capturan un área o vista generalmente trapezoidal de la superficie u objeto, teniendo el primer plano del trapezoide un distancia de muestra del

suelo substancialmente más pequeña (es decir, una mayor resolución) que el fondo del trapezoide.

Las imágenes oblicuas se consideran de poco uso o ninguno en fotogrametría. El enfoque convencional de forzar los píxeles de fondo y de primer plano de tamaños variados de una imagen oblicua en un tamaño uniforme para así combar la imagen a un sistema coordenado distorsiona dramáticamente la imagen oblicua y de esta manera hace que la identificación de objetos y la toma de mediciones de objetos ilustrados ahí sea una tarea laboriosa e imprecisa. La corrección de desplazamiento del terreno en una imagen oblicua usando un modelo de elevación distorsiona aún más las imágenes incrementando con ello la dificultad con la cual pueden hacerse las mediciones y reducir la precisión de cualquiera de esas mediciones.

Por lo tanto, a pesar de que las imágenes oblicuas se consideran como de poco uso o ninguno en fotogrametría, éstas se interpretan con facilidad y contienen información acerca de la altura de las características ilustradas en las mismas.

Por lo tanto, lo que se necesita en la técnica es un método y aparato para fotogrametría que permita la geolocalización y medición precisa en imágenes oblicuas.

Además, lo que se necesita en la técnica es un método y aparato para fotogrametría que permita la medición de alturas y de alturas relativas de objetos en la imagen.

Adicionalmente, lo que se necesita en la técnica es un método y aparato para fotogrametría que utilice imágenes más intuitivas y naturales.

BREVE DESCRIPCIÓN DE LA INVENCIÓN

La presente invención proporciona un método y aparato para capturar, visualizar, y hacer mediciones de objetos y distancias entre objetos representados en imágenes oblicuas.

La presente invención comprende, en una forma de la misma, un sistema computarizado para visualizar, geolocalizar, y hacer mediciones de imágenes oblicuas capturadas. El sistema incluye un archivo de datos accesible por medio del sistema de cómputo. El archivo de datos incluye una pluralidad de archivos de imágenes que corresponden a una pluralidad de imágenes oblicuas capturadas, y datos de posición que corresponden a las imágenes. Se ejecuta un software de visualización y análisis de imágenes a través del sistema para leer los archivos de datos y visualizar al menos una parte de las imágenes oblicuas capturadas. El software recupera los datos de posición para uno o más puntos seleccionados por el usuario en la imagen visualizada, y calcula una distancia de separación entre cualquiera de dos o más puntos elegidos. El cálculo de la distancia de separación la selecciona el usuario para determinar varios parámetros incluyendo la

distancia lineal, entre puntos seleccionados, área abarcada por los mismos, elevación relativa de los mismos, y diferencia de altura entre ellos.

BREVE DESCRIPCIÓN DE LAS FIGURAS

Las características antes mencionadas y otras y ventajas de la presente invención, y la manera de lograrlas, se evidenciarán y se entenderán completamente haciendo referencia a la siguiente descripción de una modalidad de la invención cuando se lea conjuntamente con las figuras anexas, en donde:

La figura 1 ilustra una modalidad de una plataforma o vehículo que lleva un sistema de captura de imágenes de la presente invención, y muestra imágenes ortogonales y oblicuas de ejemplo tomadas mediante el mismo;

la figura 2 es una vista diagramática del sistema de captura de imágenes de la figura 1;

la figura 3 es un diagrama de bloques del sistema de captura de imágenes de la figura 2;

la figura 4 es una representación de un archivo de datos de salida del sistema de captura de imágenes de la figura 1;

la figura 5 es un diagrama de bloques de una modalidad de un sistema de cómputo de visualización de imágenes y de medición de la presente invención para visualizar y hacer mediciones de y entre objetos representados en las imágenes capturadas por el sistema de captura de imágenes de la figura 1;

la figura 6 ilustra una imagen de ejemplo visualizada en el sistema de la figura 5, e ilustra una modalidad del método de la presente invención para la medición de y entre objetos representados en tal imagen;

las figuras 7 y 8 ilustran una modalidad de un método para capturar de imágenes oblicuas de la presente invención;

las figuras 9 y 10 ilustran una segunda modalidad de un método para capturar imágenes oblicuas de la presente invención;

Los caracteres de referencia correspondientes indican partes correspondientes a lo largo de las varias vistas. Las ejemplificaciones establecidas aquí ilustran una modalidad preferida de la invención, en una forma, y tales ejemplificaciones no se considerarán como limitantes del alcance de la invención en ninguna forma.

DESCRIPCIÓN DETALLADA DE LA INVENCIÓN

Con referencia a las figuras, y particularmente a la figura 1, se muestra una modalidad de un aparato para capturar imágenes oblicuas de geolocalización de la presente invención. El aparato 10 incluye una plataforma o vehículo 20 que lleva el sistema de captura de imágenes y de geolocalización 30.

La plataforma 20, como tal, por ejemplo, un aeroplano, trasbordador espacial, cohete, satélite, o cualquier otro vehículo, lleva el sistema de captura de imágenes 30 sobre un

área predefinida y a una o más altitudes predeterminadas arriba de la superficie 31, tal como por ejemplo, la superficie de la tierra o cualquier otra superficie de interés. Como tal, la plataforma 20 es capaz de un movimiento controlado o vuelo, ya sea tripulado o no tripulado, a lo largo de una trayectoria o curso de vuelo predefinido, por ejemplo, la atmósfera terrestre o espacio exterior. La plataforma de captura de imágenes 20 incluye un sistema para generar y regular energía (no mostrado) que incluye, por ejemplo, uno o más generadores, celdas combustibles, paneles solares, y/o baterías, para energizar el sistema de captura de imágenes 30.

El sistema de captura de imágenes y de geolocalización 30, como mejor se muestra en la figura 2, incluye dispositivos de captura de imágenes 32a y 32b, un receptor de sistema de posicionamiento global (GPS, por sus siglas en inglés) 34, una unidad de navegación inercial (INU, por sus siglas en inglés) 36, un reloj 38, un giroscopio 40, un compás 42 y un altímetro 44, cada uno de los cuales está interconectado con el sistema de cómputo de captura de imágenes 46.

Los dispositivos de captura de imágenes 32a y 32b, tales como, por ejemplo, cámaras convencionales, cámaras digitales, sensores digitales, dispositivos acoplados a carga, u otros dispositivos de captura de imágenes, son capaces de capturar

imágenes fotográficamente o electrónicamente. Los dispositivos de captura de imágenes 32a y 32b se conocen por características determinables incluyendo longitud focal, tamaño del sensor y relación de aspecto, términos de distorsión radial y otros, desviación del punto principal, paso de píxeles, y alineamiento. Los dispositivos de captura de imágenes 32a y 32b adquieren imágenes y emiten señales de datos de imágenes (IDS, por sus siglas en inglés) 48a y 48b, respectivamente, correspondientes a las imágenes particulares o fotografías tomadas y que se almacenan en un sistema de cómputo de captura de imágenes 46, como se describirá más en particular de aquí en adelante.

Como mejor se muestra en la figura 1, los dispositivos de captura de imágenes 32a y 32b tienen ejes centrales respectivos A_1 y A_2 y se montan a la plataforma 20 de tal forma que los ejes A_1 y A_2 están cada uno a un ángulo de declinación θ en relación con un plano horizontal P. El ángulo de declinación θ es virtualmente cualquier ángulo oblicuo, pero es preferentemente de aproximadamente 20° (veinte grados) a aproximadamente 60° (sesenta grados) y con mayor preferencia de aproximadamente 40° (cuarenta grados) a aproximadamente 50° (cincuenta grados).

El receptor del GPS 34 recibe señales del sistema de posicionamiento global 52 que son transmitidas por uno o más satélites del sistema de posicionamiento global 54. Las

señales de GPS 52, en forma conocida, permiten la localización precisa de la plataforma 20 en relación con la superficie 31 que va a determinarse. El receptor del GPS 34 decodifica señales del GPS 52 y emite señales/datos de localización 56, que son dependientes al menos en parte de las señales del GPS 52 y las cuales son indicativas de la localización precisa de la plataforma 20 en relación con la superficie 31, las señales/datos de localización 56 correspondientes a cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b son recibidas y almacenadas por un sistema de cómputo de captura de imágenes 46.

La INU 36 es una unidad de navegación inercial convencional que está acoplada a, y detecta cambios en la velocidad, incluyendo velocidad de traslación y rotacional, de los dispositivos de captura de imágenes 32a y 32b y/o de la plataforma 20. La INU 36 emite señales/datos de velocidad 58 indicativos de tales velocidades y/o cambios en la misma al sistema de cómputo de captura de imágenes 46, el cual almacena señales/datos de velocidad 58 correspondientes a cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b recibidos y almacenados por el sistema de cómputo de captura de imágenes 46.

El reloj 36 mantiene una medición del tiempo preciso (tiempo de validez) que se usa para sincronizar eventos en el sistema de captura de imágenes y de geolocalización 30. El

reloj 38 proporciona una señal de datos/reloj de tiempo 62 que es indicativa del tiempo preciso en que una imagen es tomada por los dispositivos de captura de imágenes 32a y 32b. Los datos de tiempo 62 se proveen también y se almacenan por el sistema de cómputo captura de imágenes 46. Alternativamente, el reloj 38 está integrado con el sistema de cómputo de captura de imágenes 46, tal como, por ejemplo, un programa de software de reloj.

El giroscopio 40 es un giroscopio convencional encontrado en aeroplanos y/o en sistemas de navegación comerciales para aeroplanos. El giroscopio 40 proporciona señales incluyendo señales de inclinación 64, señales balanceo 66, y señales de guiñada 68, los cuales son indicativos de la inclinación, balanceo y guiñada de la plataforma 20. La señal de inclinación 64, la señal de balanceo 66 y la señal de guiñada 68 correspondientes a cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b son recibidas y almacenadas por el sistema de cómputo de captura de imágenes 46.

El compás 42, tal como, por ejemplo, un compás electrónico convencional, indica el rumbo de la plataforma 20. El compás 42 emite una señal/dato de rumbo 72 indicativo del rumbo de la plataforma 20. El sistema de cómputo de captura de imágenes 46 recibe y almacena señales/datos de rumbo 72 que corresponden a cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b.

El altímetro 44 indica la altitud de la plataforma 20. El altímetro 44 emite una señal/dato de altitud 74, y un sistema de cómputo de captura de imágenes 46 recibe y almacena la señal/dato de altitud 74 que corresponde a cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b.

Como mejor se muestra en la figura 3, el sistema de cómputo de captura de imágenes 46, tal como, por ejemplo, una computadora personal portátil convencional, incluye una memoria 82, dispositivos de entrada de datos 84a y 84b, un dispositivo de visualización 86, y puertos de entrada y salida (I/O, por sus siglas en inglés) 88. El sistema de cómputo de captura de imágenes 46 ejecuta un software de adquisición de imágenes y datos 90, el cual se almacena en la memoria 82. La memoria 82 también almacena datos usados y/o calculados por el sistema de cómputo de captura de imágenes 46 durante la operación del mismo, e incluye, por ejemplo, una memoria no volátil de solo lectura, una memoria de acceso aleatorio, una memoria de disco duro, tarjetas de memorias removibles y/u otros dispositivos y/o medios de memoria adecuados. Los dispositivos de entrada de datos 84a y 84b, tales como, por ejemplo, un ratón, teclado, palanca de control, u otro de tales dispositivos de entrada de datos, permiten la entrada de datos y la interacción de un usuario con software que se ejecuta por el sistema de cómputo de

captura de imágenes 46. El dispositivo 86, tal como, por ejemplo, una pantalla de cristal líquido o tubo de rayos catódicos, presenta información al usuario del sistema de cómputo de captura de imágenes 46. Los puestos de I/O 88, tales como, por ejemplo, puertos seriales y paralelos de entrada y salida de datos, permiten la entrada y/o salida de datos del sistema de cómputo de captura de imágenes 46.

Cada una de las señales de datos antes descritas se conecta con el sistema de cómputo de captura de imágenes 46. Más particularmente, las señales de datos de imágenes 48, señales de localización 56, señales de velocidad 58, señal de datos de tiempo 62, señales de inclinación, balanceo y guiñada 64, 66 y 68, respectivamente, señal de rumbo 72 y señal de altitud 74 son recibidas vía los puestos I/O 88 y almacenadas en la memoria 82 del sistema de cómputo de captura de imágenes 46.

En el uso, el sistema de cómputo de captura de imágenes 46 ejecuta el software de adquisición de datos de imágenes 90, el cual, en general, controla la lectura, manipulación, y almacenamiento de las señales de datos antes descritas. Más particularmente, el software de adquisición de imágenes y datos 90 lee señales de datos de imágenes 48a y 48b y los almacena en la memoria 82. Cada una de las señales de localización 56, señales de velocidad 58, señales de datos de tiempo 62, señales de inclinación, balanceo y guiñada 64, 66

y 68, respectivamente, señal de rumbo 72 y señal de altitud 74 que representan las condiciones existentes en el instante en que se adquiere o captura una imagen por los dispositivos de captura de imágenes 32a y 32b y que corresponden a las señales de datos de imágenes particulares 48a y 48b que representan las imágenes capturadas son recibidas por el sistema de cómputo de captura de imágenes 46 a través de los puertos I/O 88. El sistema de cómputo de captura de imágenes 46 que ejecuta el software de adquisición de imágenes y datos 90 emite una señal de captura de imágenes 92 a los dispositivos de captura de imágenes 32a y 32b para ocasionar con ello que los dispositivos adquieran o capturen una imagen en sitios predeterminados y/o a intervalos predeterminados que son dependientes al menos en parte de la velocidad de la plataforma 20.

El software de adquisición de imágenes y datos 90 decodifica según sea necesario y almacena las señales antes mencionadas en la memoria 82, y asocia las señales de datos con señales de imágenes correspondientes 48a y 48b. Por lo tanto, se conoce la altitud, la orientación en términos de balanceo, inclinación, y guiñada, y la ubicación de los dispositivos de captura de imágenes 32a y 32b en relación con la superficie 31, es decir, longitud y latitud, para cada imagen capturada por los dispositivos de captura de imágenes 32a y 32b.

La plataforma 20 es piloteada o de otra manera guiada a través de una trayectoria de captura de imágenes que pasa a través de un área particular de superficie 31, tal como, por ejemplo, un área predefinida de la superficie de la tierra o de otro planeta. Preferentemente, la trayectoria de captura de imágenes de la plataforma 20 está a ángulos rectos con al menos uno de los límites del área de interés. El número de veces que la plataforma 20 y/o los dispositivos de captura de imágenes 32a, 32b pasa a través del área de interés es dependiente al menos en parte del tamaño del área y cantidad de detalle deseado en las imágenes capturadas. Los detalles particulares de la trayectoria de captura de imágenes de la plataforma 20 se describen con más particularidad de aquí en adelante.

Al pasar la plataforma 20 a través del área de interés se captura un número de imágenes oblicuas por los dispositivos de captura de imágenes 32a y 32b. Tal como lo entenderán aquellos con experiencia en la técnica, las imágenes son capturadas o adquiridas por los dispositivos de captura de imágenes 32a y 32b a intervalos de captura de imágenes predeterminados los cuales son dependientes al menos en parte de la velocidad de la plataforma 20.

Las señales de datos de imágenes 48a y 48b que corresponden a cada imagen adquirida son recibidas por y almacenadas en la memoria 82 del sistema de cómputo de

captura de imágenes 46 a través de los puertos I/O 88. Similarmente, las señales de datos (es decir, señales de datos de imágenes 48, señales de localización 56, señales de velocidad 58, señal de datos de tiempo 62, señales de inclinación, balanceo y guiñada 64, 66 y 68, respectivamente, señal de rumbo 72 y señal de altitud 74) correspondientes a cada imagen capturada son recibidas y almacenadas en la memoria 82 del sistema de cómputo de captura de imágenes 46 a través de los puertos I/O 88. Por lo tanto, el dispositivo de captura de imágenes 32a y 32b en relación con la superficie 32 en el momento preciso que cada imagen es capturada es registrada en la memoria 82 y asociada con la imagen capturada correspondiente.

Como mejor se muestra en la figura 1, la localización de los dispositivos de captura de imágenes 32a y 32b en relación con la tierra corresponde al punto nadir N de la imagen ortogonal 102. Por lo tanto, la geolocalización exacta del punto nadir N de la imagen ortogonal 102 es indicada por las señales de localización 56, las señales de velocidad 58, la señal de datos de tiempo 62, señales de inclinación, balanceo y guiñada 64, 66 y 68, respectivamente, la señal de rumbo 72 y la señal de altitud 74. Una vez que se conoce el punto nadir N de la imagen ortogonal 102, la geolocalización de otro píxel o punto en la imagen 102 puede determinarse de manera conocida.

Cuando los dispositivos de captura de imágenes 32a y 32b capturan imágenes oblicuas, tales como las imágenes 104 a y 104b (figura 1), la localización de los dispositivos de captura de imágenes 32a y 32b en relación con la superficie 31 es indicada similarmente por las señales de localización 56, las señales de velocidad 58, la señal de datos de tiempo 62, las señales de inclinación, balanceo y guiñada 64, 66 y 68, respectivamente, la señal de rumbo 72, la señal de altitud 74 y el ángulo de declinación conocido θ de los ejes principales A_1 y A_2 de los dispositivos de captura de imágenes 32a y 32b, respectivamente.

Particularmente deberá notarse que un proceso calibración permite que el software de adquisición de imágenes y datos 90 incorpore factores de corrección y/o corrija cualquier error inherente o debido al dispositivo de captura de imágenes 32, tal como, por ejemplo, error debido a la longitud focal calibrada, tamaño del sensor, distorsión radial, desviación del punto principal, y alineación.

El software de adquisición de imágenes y datos 90 crea y almacena en la memoria 82 uno o más archivos de imágenes y datos de salida 120. Más particularmente, el software de adquisición de imágenes y datos 90 convierte señales de imágenes de datos 48a, 48b y las señales de datos de orientación (es decir, señales de datos de imágenes 48, señales de localización 56, señales de velocidad 58, señal de

datos de tiempo 62, señales de inclinación, balanceo y guiñada 64, 66 y 68, respectivamente, señal de rumbo 72 y señal de altitud 74) en archivos de imágenes y datos de salida de lectura por computadora 120. Como mejor se muestra en la figura 4, el archivo de imágenes y datos de salida 120 contiene una pluralidad de archivos de imágenes capturadas I_1, I_2, ..., I_n correspondientes a imágenes oblicuas capturadas, y los datos de posición C_{PD1}, C_{PD2}, ..., C_{PDn} que corresponden a las mismas.

Los archivos de imágenes I_1, I_2, ..., I_n del archivo de imágenes y datos 120 se almacenan virtualmente en cualquier formato de archivo de imágenes o gráficos de lectura por computadora, tal como, por ejemplo, formatos de archivo JPEG, TIFF, GIF, BMP, o PDF, y tienen referencias cruzadas con los datos de posición C_{PD1}, C_{PD2}, ..., C_{PDn} los cuales se almacenan también como datos de lectura por computadora. Alternativamente, los datos de posición C_{PD1}, C_{PD2}, ..., C_{PDn} están integrados con los archivos de imágenes correspondientes I_1, I_2, ..., I_n en forma conocida. Los archivos de datos de imágenes 120 son procesados después, ya sea por medio de software de adquisición de imágenes y datos 90 o por procesamiento posterior, para corregir errores, tales como, por ejemplo, errores debido a desviaciones de la trayectoria de vuelo y otros errores conocidos por aquellos con experiencia en la técnica. Posteriormente, los archivos

de datos de imágenes 120 están listos para usarse para visualizar y hacer mediciones de, y entre los objetos representados en las imágenes capturadas, incluyendo mediciones de las alturas de tales objetos.

Con referencia ahora a la figura 5, el sistema de cómputo de visualización y medición de imágenes 130, tal como, por ejemplo, una computadcra personal de escritorio convencional o una terminal computadora móvil en un automóvil de policía, incluye la memoria 132, dispositivos de entrada de datos 134a y 134b, el dispositivo de visualización 136, y la conexión a red 138. El sistema de cómputo de captura de imágenes 130 ejecuta el software de visualización y análisis de imágenes 140, el cual se almacena en la memoria 132. La memoria 132 incluye, por ejemplo, la memoria de solo lectura no volátil, la memoria de acceso aleatorio, la memoria de disco duro, tarjetas de memoria removibles y/u otros dispositivos y/o medios de almacenamiento de memoria adecuados. Los dispositivos de entrada de datos 134a y 134b, tales como, por ejemplo, un ratón, teclado, palanca de control, u otros dispositivos de entrada de datos, permiten la entrada de datos y la interacción de un usuario con el software de visualización y análisis de imágenes 140 que se ejecuta por el sistema de cómputo de visualización y medición de imágenes 130. El dispositivo de visualización 136, tal como, por ejemplo, una pantalla de cristal líquido o un tubo

de rayos catódicos, visualiza información al usuario del sistema de cómputo de visualización y medición de imágenes 130. La conexión de red 138 conecta el sistema de cómputo de visualización y medición de imágenes 130 a una red (no mostrada), tal como, por ejemplo, una red de área local, una red de área amplia, la Internet y/o la Red Mundial.

En el uso, y con referencia ahora a la figura 6, el sistema de cómputo de visualización y medición de imágenes 130 que ejecuta software de visualización y análisis de imágenes 140 accede a uno o más archivos de imágenes y datos de salida 120 que han sido leídos en la memoria 132, tal como, por ejemplo, a través de una conexión de red 138, una unidad de disco flexible, una tarjeta de memoria removible u otro medio adecuado. Una o más de las imágenes capturadas I_1, I_2, ..., I_n de los archivos de imágenes y datos de salida 120 se visualizan posteriormente como imágenes oblicuas visualizadas 142 bajo el control del software de visualización y análisis de imágenes 140. Aproximadamente al mismo tiempo, una o más porciones de datos C_{PD1}, C_{PD2}, ..., C_{PDn} que corresponden a la imagen oblicua 142 son leídas en una porción fácilmente accesible de la memoria 132.

Deberá notarse particularmente que la imagen oblicua visualizada 142 se visualiza substancialmente tal como es capturada, es decir, la imagen visualizada 142 no está combada o ajustada a algún sistema coordenado tampoco está

ortorrectificada la imagen visualizada 142. En lugar de combar la imagen visualizada 142 a un sistema coordenado con el objeto de permitir la medición de los objetos representados en la misma, el software de visualización y análisis de imágenes 140, en general, determina las geolocalizaciones de píxeles seleccionados solo según sea necesario, o "dinámicamente", referenciando porciones de datos C_{PD1}, C_{PD2}, ..., C_{PDn} de archivos de imágenes y datos de salida 120 y calculando la posición y/o geolocalización de aquellos píxeles seleccionados usando una o más ecuaciones de proyección como se describe con más particularidad de aquí en adelante.

Generalmente, un usuario del sistema de cómputo de visualización y medición de imágenes 130 hace mediciones de y entre los objetos representados en la imagen oblicua visualizada 142 y seleccionando uno de varios modos de medición disponibles provistos en el software de visualización y análisis de imágenes 140. El usuario selecciona el modo de medición deseado accediendo, por ejemplo, a una serie de menús desplegables o barras de herramientas M, o por medio de comandos del teclado. Los modos de medición proporcionados por el software de visualización y análisis de imágenes 140 incluye, por ejemplo, un modo de distancia que permite la medición de la distancia entre dos o más puntos seleccionados, un modo de

área que permite la medición del área abarcada por varios puntos seleccionados e interconectados, un modo de altura que permite la medición de la altura entre dos o más puntos seleccionados, y un modo de elevación que permite la medición del cambio en la elevación de un punto seleccionado en relación con uno o más de los otros puntos seleccionados.

Después de seleccionar el modo de medición deseado, el usuario del software de visualización y análisis de imágenes 140 selecciona con uno de los dispositivos de entrada de datos 134a, 134b un punto inicial o píxel inicial 152 y un punto o píxel final 154 en la imagen visualizada 142, y el software de visualización y análisis de imágenes 140 calcula y visualiza automáticamente la cantidad observada, tal como por ejemplo, la distancia entre el píxel inicial 152 y el píxel final 154.

Cuando el usuario selecciona el punto/píxel inicial 152, la gelocalización del punto correspondiente al mismo sobre la superficie 31 se calcula por medio del software de visualización y análisis de imágenes 140 el cual ejecuta una o más ecuaciones de proyección usando las porciones de datos C_{PD1}, C_{PD2}, ..., C_{PDn} de los archivos de imágenes y datos de salida 120 que corresponden a la imagen particular que está siendo visualizada. La longitud y altitud del punto sobre la superficie 31 correspondiente al píxel 152 se visualizan entonces por medio del software de visualización y análisis

de imágenes 140 en la pantalla 136, tal como, por ejemplo, por súper imposición de la longitud y latitud en la imagen visualizada 142 adyacente al punto/píxel seleccionado o en el bloque de visualización emergente en cualquier parte de la pantalla 136. El mismo proceso es repetido por el usuario para la selección del píxel/punto final 154, y por el software de visualización y análisis de imágenes 140 para la recuperación y visualización de la información de longitud y latitud.

El cálculo de la distancia entre los puntos/píxeles iniciales y finales 152, 154, respectivamente, se logra determinando la geolocalización de cada píxel seleccionado 152, 154 "dinámicamente". Las porciones de datos C_{PD1}, C_{PD2}, ..., C_{PDn} del archivo de imágenes y datos de salida 120 que corresponden a la imagen visualizada se recuperan, y se determina la geolocalización del punto en la superficie 31 correspondiente a cada píxel seleccionado. La diferencia entre las geolocalizaciones correspondientes a los píxeles seleccionados determina la distancia entre los píxeles.

Como ejemplo de cómo se determina la geolocalización de un punto o píxel dado en la imagen oblicua visualizada 142, supondremos que la imagen visualizada 142 corresponde a la imagen ortogonal 104a (figura 1). El usuario del software de visualización y análisis de imágenes 140 selecciona el píxel 154, el cual, por simplicidad, corresponde al centro C

(figura 1) de la imagen oblicua 104a. Tal como se muestra en la figura 1, la línea 106 se extiende a lo largo del plano horizontal G desde un punto 108 sobre el mismo que está directamente debajo del dispositivo de captura de imágenes 32a al centro C del límite o borde cercano 108 de la imagen oblicua 104a. Una extensión del eje principal A_1 interseca con el centro C. El ángulo ϕ es el ángulo formado entre la línea 106 y la extensión del eje principal A_1. Por lo tanto, se forma un triángulo (sin referencias) que tiene vértices en el dispositivo de captura de imágenes 32a, el punto 108 y el centro C, y que tiene lados 106, la extensión del eje principal A_1 y la línea vertical (punteada) 110 entre el punto 108 u el dispositivo de captura de imágenes 32a.

El plano del suelo G es un plano de suelo substancialmente horizontal, plano o sin pendientes (y el cual típicamente tendrá una elevación que refleja la elevación promedio del terreno), y por lo tanto el triángulo antes descrito incluye un ángulo recto entre el lado/línea 110 y el lado/línea 106. Dado que el ángulo ϕ y la altitud del dispositivo de captura de imágenes 32 (es decir, la longitud del lado 110) se conocen, la hipotenusa (es decir, la longitud de la extensión del eje principal A_1) y el otro lado restante del triángulo recto se calcula por geometría simple. Además, dado que la posición exacta del dispositivo de captura de imágenes 32a se conoce en el momento en el que

se capturó la imagen correspondiente a la imagen visualizada 142, se conocen la latitud y longitud del punto 108. Conociendo la longitud del lado 106, calculada como se describió anteriormente, permite la geolocalización exacta del píxel 154 correspondiente al centro CX de la imagen oblicua 104a que va determinarse por el software de visualización y análisis de imágenes 140. Una vez que se conoce la geolocalización del punto que corresponde al píxel 154, la geolocalización de cualquier otro píxel en la imagen oblicua visualizada 142 puede determinarse usando las características de cámara conocidas, tales como, por ejemplo, longitud focal, tamaño del sensor y relación de aspecto, término radial y otros términos de distorsión, etc.

La distancia entre dos o más puntos que corresponden a dos o más píxeles seleccionados en la imagen visualizada 142 se calcula por medio del software de visualización y análisis de imágenes 140 determinando la diferencia entre las geolocalizaciones de los píxeles seleccionados usando algoritmos conocidos, tales como por ejemplo, la fórmula de Gauss y/o la fórmula del punto de desvanecimiento, dependiente del modo de medición seleccionado. La medición de los objetos representados o que aparecen en la imagen visualizada 142 se lleva a cabo por medio de un procedimiento substancialmente similar al procedimiento descrito arriba para medir distancias entre píxeles seleccionados. Por

ejemplo, las longitudes anchuras y alturas de objetos, tales como, por ejemplo, edificios, ríos, caminos, y virtualmente cualquier otra estructura geográfica o construida por el hombre, que aparece en la imagen visualizada 142 es medida seleccionando el modo de medición apropiado/deseado y seleccionando los píxeles iniciales y finales.

Deberá notarse particularmente que en el modo de medición de distancia el software de visualización y análisis de imágenes 140 la distancia entre los puntos/píxeles iniciales y finales 152, 154, respectivamente, es determinable a lo largo de virtualmente cualquier trayectoria, tal como, por ejemplo, una trayectoria en "línea recta" P1 o una trayectoria P2 que involucra la selección de puntos/píxeles intermedios y uno o más segmentos de "línea recta" interconectados ahí.

También deberá notarse particularmente que el modo de medición de la distancia del software de visualización y análisis de imágenes 140 determina la distancia entre píxeles seleccionados de conformidad con el método "recorre la tierra". El método "recorre la tierra" crea una serie de segmentos de líneas interconectadas, representadas colectivamente por las trayectorias P1 y P2, que se extienden entre los píxeles/puntos selecciones y los cuales se ubican o se conforman a las caras planas de una serie de facetas interconectadas que definen un plano terrestre teselado. El

plano terrestre teselado, como se describirá con más particularidad a continuación, sigue cercanamente o recrea el terreno de la superficie 31, y por lo tanto las trayectorias P1 y P2 siguen también cercanamente el terreno de la superficie 31. Al medir la distancia a lo largo del terreno simulado por el plano terrestre teselado, el método de "recorre la tierra" proporciona una medición más precisa y útil de la distancia entre puntos seleccionados que el enfoque convencional, el cual comba la imagen sobre una tierra plana o sistema plano de elevación promedio y mide la distancia entre puntos seleccionados a lo largo de la tierra plana o plano e ignora substancialmente variaciones en el terreno entre los puntos.

Por ejemplo, un contratista que prepara un oferta acerca de un contrato para pavimentar una calzada sobre un terreno desigual o con cuestas puede determinar la cantidad aproximada o área de camino involucrado usando el software de visualización y análisis de imágenes 140 y el método de medición de "recorre la tierra" provisto en el mismo. El contratista puede obtenerla cantidad aproximada o área de calzada desde su propia oficina sin haber enviado una cuadrilla de reconocimiento al sitio para obtener las mediciones necesarias.

En contraste con el método de "recorre la tierra" proporcionado por la presente invención, los enfoques de

cálculo de "tierra plana" o de distancia de elevación promedio incluyen imprecisiones inherentes cuando se miden las distancias entre puntos y/u objetos dispuestos en un terreno disparejo y cuando se miden los tamaños y/o alturas de los objetos similarmente dispuestos. Aún una pendiente modesta o grado en la superficie que es capturada resulta en una diferencia en la elevación del punto nadir en relación con virtualmente cualquier otro punto de interés en la misma. Por lo tanto, con referencia nuevamente a la figura 1, el triángulo formado por la línea 106, la extensión del eje principal A_1 y la línea vertical (punteada) 110 entre el punto 108 y el dispositivo de captura de imágenes 32a no pueden estar en un ángulo recto. Si tal es el caso, cualquier cálculo geométrico que suponga que el triángulo sea un triángulo recto podría contener errores, y tales cálculos se reducirían a aproximaciones debido todavía a un gradiente o pendiente relativamente ligero entre los puntos de interés.

Por ejemplo, si la superficie 31 se inclina hacia arriba entre el punto nadir N y el centro C cerca o en el borde inferior 108 de la imagen oblicua 104 entonces la segunda línea 110 interseca la superficie 31 antes de que el punto en el cual tal intersección ocurriese en un nivel o superficie sin pendiente 31. Si el centro C es 4.57 metros (quince pies) más grande que el punto nadir N y con un ángulo de declinación θ igual a 40° (cuarenta grados), la localización

calculada del centro C sería aproximadamente de 5.42 metros (17.8 pies) sin corrección para el cambio en la elevación entre los puntos.

Tal como se discutió en general anteriormente, con el objeto de compensar al menos en parte los cambios en elevación y las imprecisiones resultantes en la medición de y entre objetos en la imagen 142, el software de visualización y análisis de imágenes 140 coloca referencias, como se requiera, en puntos en la imagen visualizada 142 y sobre la superficie 31 a un plano terrestre teselado o con facetas precalculado designado en general como 160 en la figura 6. El plano terrestre teselado 160 incluye una pluralidad de facetas individuales 162a, 162b, 162c, etc., cada uno de los cuales está interconectada una con la otra y están definidas por cuatro vértices (sin referencias, pero mostrados como puntos) teniendo elevaciones respectivas. Los pares adyacentes de las facetas 162a, 162b, 162c, etc., comparten dos vértices. Cada faceta 162a, 162b, 162c, etc., tiene una inclinación y pendiente respectiva. El plano terrestre teselado 160 se crea con base en varios datos y recursos, tales como, por ejemplo, mapas topográficos, y/o gráficos de tramas digitales, datos de reconocimiento, y varias otras fuentes.

Generalmente, la geolocalización de un punto de interés en la imagen visualizada 142 se calcula determinando cuál de las facetas 162a, 162b, 162c, etc., corresponde a ese punto

de interés. Por lo tanto, la localización del punto de interés se calcula con base en las características, es decir, elevación, inclinación y pendiente, de las facetas 162a, 162b, 162c, etc., en lugar que sea con base en un plano o plano terrestre de elevación promedio. El error se introduce en el grado en el que la topografía de la superficie 31 y la localización del punto de interés en la misma de desvía de la superficie plana de las facetas 162a, 162b, 162c, etc., en las cuales se ubica el punto de interés. Ese error es reducible a través de una interpolación bilineal de la elevación del punto de interés en una de las facetas particulares 162 a, 162b, 162c, etc., y usando esa elevación interpolada en el calculo de localización efectuado por el software de visualización y análisis de imágenes 140.

Para usar el plano terrestre teselado 160, el software de visualización y análisis de imágenes 140 emplea un algoritmo de rastreo de rayo modificado para encontrar la intersección del rayo proyectado del dispositivo de captura de imágenes 32a ó 32b hacia la superficie 31 y el plano terrestre teselado 160. El algoritmo determina no solo cuál de las facetas 162a, 162b, 162c, etc., es intersecada por el rayo, sino también en qué lugar en la faceta tiene lugar la intersección. Mediante el uso de la interpolación bilineal, puede determinarse una localización terrestre bastante precisa. Para la proyección inversa, el plano terrestre

teselado 160 se usa para encontrar el valor de elevación del terreno para la localización terrestre de entrada usando también la interpolación bilineal. La elevación y localización se usan después para proyectar hacia atrás a través de un modelo del dispositivo de captura de imágenes 32a y 32b para determinar cuál de los píxeles en la imagen visualizada 142 corresponde a la localización dada.

Más en particular, y como un ejemplo, el software de visualización y análisis de imágenes 140 ejecuta y/o calcula la geolocalización del punto 164 superponiendo y/o ajustando el plano terrestre teselado 160 a al menos una porción 166, tal como, por ejemplo, una loma, de superficie 31. Deberá notarse que solo una pequeña porción del plano terrestre teselado 160 y las facetas 162a, 162b, 162c, etc., del mismo se muestra a lo largo del perfil de la porción 166 de la superficie 31. Como se discutió anteriormente, cada una de las facetas 162a, 162b, 162c, etc., se define por medio de cuatro vértices, cada uno de os cuales tiene elevaciones respectivas y cada una de las facetas tiene inclinaciones y pendientes respectivas. La posición de la pendiente del punto 164 sobre el plano/superficie de la faceta 162a, 162b, 162c, etc., en el cual se ubica el punto 164 (o su proyección) se determina como se describió anteriormente.

El plano terrestre teselado 160 se crea preferentemente fuera de la operación del sistema de cómputo de visualización

y medición de imágenes 130 y del software de visualización y análisis de imágenes 140. En su lugar, el plano terrestre 160 toma la forma de una tabla de datos relativamente simple o tabla de consulta 168 almacenada en la memoria 132 de y/o accesible al sistema de cómputo de visualización y medición de imágenes 130. Los recursos de cómputo requeridos para calcular las localizaciones de todos los vértices de las muchas facetas de un plano terrestre típico no necesariamente tiene que residir en el sistema de cómputo de visualización y medición de imágenes 130. Por lo tanto, el sistema de cómputo de visualización y medición de imágenes 130 es compatible para usarse y ejecutarse por una computadora personal convencional sin requerir recursos de cómputo adicionales.

El cálculo del plano terrestre teselado 160 fuera del sistema de cómputo de visualización y medición de imágenes 130 permite que se incorpore virtualmente cualquier nivel de detalle en el plano terrestre teselado 160, es decir, el tamaño y/o área cubierta por, o que corresponde a, cada una de las facetas 162a, 162b, 162c, etc., puede ser tan grande o tan pequeño como se desee, sin aumentar significativamente el tiempo de cálculo, ni retardar la operación, ni aumentar significativamente los recursos requeridos por el sistema de cómputo de visualización y medición de imágenes 130 y/o el software de visualización y análisis de imágenes 140. El sistema de cómputo de visualización y medición 130 puede por

lo tanto ser un sistema de cómputo relativamente básico y no complicado.

El tamaño de las facetas 162a, 162b, 162c, etc., son de tamaño uniforme a través de una imagen visualizada particular 142. Por ejemplo, si la imagen visualizada 142 corresponde a un área que es aproximadamente de 228.6 metros (750 pies) de ancho en el primer plano por aproximadamente 274.3 metros (900 pies) de profundidad, la imagen puede partirse en facetas que son de aproximadamente 4.6 metros cuadrados (50 pies cuadrados), produciendo por lo tanto 15 facetas de ancho y 18 facetas de profundidad. Alternativamente, los lados de las facetas 162a, 162b, 162c, etc., son uniformes en términos de número de píxeles contenidos en las mismas, es decir cada faceta es del mismo número de píxeles de ancho y el mismo número de píxeles de profundidad. Las facetas en el primer plano de la imagen visualizada 142, en donde la densidad de píxeles es la mayor, serían por lo tanto dimensionalmente más pequeñas que las facetas en el fondo de la imagen visualizada 142 en donde la densidad de píxeles en la menor. Dado que es deseable hacer más mediciones en el primer plan o de una imagen visualizada en donde la densidad de píxeles es la mayor, la creación de facetas que son uniformes en términos del número de píxeles que contienen tiene la ventaja de proporcionar mediciones más precisas en el primer plano de la imagen visualizada 142 en relación con las facetas que son dimensionalmente uniformes.

Otra ventaja del uso de píxeles como una base para definir las dimensiones de las facetas 162a, 162b, 162c, etc., es que el cálculo de localización (localización del píxel con respecto a la localización del terreno) es relativamente simple. Un usuario opera el sistema de cómputo de visualización y medición de imágenes 130 para seleccionar un píxel en una faceta dada, el software de visualización y análisis de imágenes 140 consulta los datos para la faceta que corresponde al píxel seleccionado, la elevación del píxel seleccionado se calcula como se discutió anteriormente, y esa elevación se usa en el cálculo de localización.

Generalmente, el método de captura de imágenes oblicuas de la presente invención divide un área de interés, tal como, por ejemplo, un condado, en sectores de tamaño generalmente uniforme, tales como, por ejemplo, sectores que son de aproximadamente 2.6 kilómetros cuadrados (una milla cuadrada) de área. Esto se hace para facilitar la creación de un plan de vuelo para capturar imágenes oblicuas que cubren cada centímetro (pulgada) del área de interés, y para organizar y nombrar los sectores y/o imágenes de la misma para fácil referencia, almacenamiento y recuperación (un proceso conocido en la técnica como "sectorización"). Debido a que los bordes de cualquier área geográfica de interés, tal como un condado, rara vez caen dentro de límites de kilómetros cuadrados (millas cuadradas) uniformes, el método de captura

de imágenes oblicuas de la presente invención proporciona más sectores que las millas cuadradas que existen en el área de interés - cuánto más depende en gran medida de la longitud de los límites del condado así como que tan rectos o dentados están. Típicamente, se puede esperar un sector adicional por cada 3.2 a 4.8 kilómetros (dos a tres millas) de límite. Por lo tanto si un condado u otra área de interés es de aproximadamente 32.2 kilómetros (20 millas) por 56.3 kilómetros (35 millas), ó 1813 kilómetrcs cuadrados (700 millas cuadradas), el área se dividirá en aproximadamente 740 a 780 sectores.

El método de captura de imágenes oblicuas de la presente invención, en general captura las imágenes oblicuas de al menos dos direcciones de compás, y proporciona cobertura total del área de interés de al menos esas dos direcciones de compás. Con referencia ahora a las figuras 7 y 8, se muestra una primera modalidad de un método para capturar imágenes oblicuas de la presente invención. Por claridad, las figuras 7 y 8 se basan en un sistema que tiene solo un dispositivo de captura de imágenes. Sin embargo, se entenderá que pueden usarse dos o más dispositivos de captura de imágenes.

El dispositivo de captura de imágenes captura una o más imágenes durante cada área recorrida 200. El dispositivo de captura de imágenes, como se discutió anteriormente, es dirigido a un ángulo sobre el área 200 para capturar las

imágenes oblicuas de la misma. El área 200 es atravesada en un patrón de ida y vuelta, similar a la manera en la que el césped es segado, por el dispositivo portador de imágenes y/o la plataforma para asegurar la doble cobertura del área 200.

Más en particular, el área 200 es atravesada por el dispositivo portador de imágenes 32 y/o plataforma 20 siguiendo una primera trayectoria 202 para capturar de esta manera imágenes oblicuas de las porciones 202a, 202b, y 202c del área 200. El área 200 es atravesada después por el dispositivo portador de imágenes 32 y/o la plataforma 20 siguiendo un segundo patrón 204 que es paralelo y está espaciado de, y en una dirección opuesta a, es decir, 180° (ciento ochenta grados) de, la primera trayectoria 202, para capturar así imágenes oblicuas de las porciones 204a, 204b, 204c del área 200. Comparando las figuras 7 y 8, se observa que una porción 207 (figura 8) del área 200 está cubierta por las imágenes 202a-c capturadas de una primera dirección o perspectiva, y por la imágenes 204a-c capturadas de una segunda dirección o perspectiva. Como tal, la porción intermedia 200 es doblemente cubierta al 100% (cien por ciento). El patrón antes descrito de atravesar o pasar sobre el área 200 a lo largo de trayectorias opuestas que son paralelas a las trayectorias 202 y 204 se repite hasta que toda el área 200 está completamente cubierta por al menos una imagen oblicua capturada de las trayectorias que son

paralelas, y están espaciadas, una de la otra como lo establece el tamaño del área 200, y en la misma dirección que las trayectorias 202 y 204 para así cubrir doblemente el área 200 en un cien por ciento desde estas perspectivas/direcciones.

Si se desea, y para un detalle mejorado, el área 200 es cubierta por la tercera y cuarta trayectorias opuestas y paralelas adicionales 206 y 208, respectivamente, que son perpendiculares a las trayectorias 202 y 204 como se muestran en las figuras 9 y 10. El área 200 es por lo tanto atravesada por el dispositivo portador de imágenes 32 y/o la plataforma 20 siguiendo la trayectoria 206 para capturar imágenes oblicuas de las porciones 206a, 206b y 206c del área 200, y después es atravesada a lo largo de la cuarta trayectoria 208 que es paralela, está espaciada de, y opuesta a la tercera trayectoria 206 para capturar imágenes oblicuas de las porciones 208a, 208b y 208c del área 200. Este patrón e atravesar o pasar sobre el área 200 a lo largo de trayectorias opuestas que son paralelas a las trayectorias 206 y 208 se repite similarmente hasta que toda el área 200 está completamente cubierta por al menos una imagen oblicua capturada de las trayectorias que son paralelas a, y estás espaciadas de, como lo establece el tamaño del área 200, y en la misma dirección que las trayectorias 206 y 208 para así cubrir doblemente el área 200 en un cien por ciento de esas direcciones/perspectivas.

Como se describió anteriormente, el dispositivo portador de imágenes 32 y/o la plataforma 20, atraviesa o pasa sobre el área 200 a lo largo de una trayectoria predeterminada. Sin embargo, deberá entenderse que el dispositivo portador de imágenes y/o la plataforma 20 no necesariamente pasa o atraviesa directamente sobre el área 200 sino más bien puede pasar o atravesar un área adyacente, cercana a, o aún un tanto retirada del área 200 con el objeto de asegurar que la porción de área 200 que está siendo captada cae dentro del campo de captura de imagen del dispositivo de captura de imágenes. La trayectoria 202, como se muestra en la figura 7, es una trayectoria tal que no pasa directamente sobre el área 200 pero captura aún imágenes oblicuas de la misma.

La presente invención es capaz de capturar imágenes en varios niveles de resolución y distancias de muestras de terreno. Un primer nivel de detalle, al cual se le hace referencia de aquí en adelante como nivel de comunidad, tiene una distancia de muestra de terreno de, por ejemplo, aproximadamente 0.6 metros (dos pies) por píxel. Para imágenes a nivel de comunidad ortogonales, la distancia de muestra terrestre permanece substancialmente constante a través de la imagen. Las imágenes a nivel de comunidad ortogonales son capturadas con suficiente traslape para proporcionar una cobertura de par estéreo. Para imágenes a nivel de comunidad oblicuas, la distancia de muestra

terrestre varía de, por ejemplo, aproximadamente 0.3 metros (un pie) por píxel en el primer plano de la imagen a aproximadamente 0.6 metros (dos pies) por píxel en la mitad del terreno de la imagen, y hasta aproximadamente 1.2 metros (cuatro pies) por píxel en el fondo de la imagen. Las imágenes a nivel de comunidad oblicuas son capturadas con suficiente traslape de tal manera que cada área de interés está cubierta típicamente por al menos dos imágenes oblicuas de cada dirección de compás capturada. Aproximadamente se capturas diez imágenes a nivel de comunidad oblicuas por sector.

Un segundo nivel de detalle, de aquí en adelante referenciado como nivel de vecindario, está significativamente más detallado que las imágenes a nivel de comunidad. La imágenes a nivel de vecindario tienen una distancia de muestra terrestre de, por ejemplo, aproximadamente 15.24 centímetros (seis pulgadas) por píxel. Para imágenes a nivel de vecindario ortogonales, la distancia de muestra terrestre permanece substancialmente constante. Las imágenes a nivel de vecindario oblicuas tienen una distancia de muestra terrestre de, por ejemplo, aproximadamente (cuatro pulgadas) por píxel en el primer plano de la imagen a aproximadamente seis pulgadas por píxel en el terreno medio de la imagen, y hasta aproximadamente 25.4 centímetros (diez pulgadas) por píxel en el fondo de la imagen. Las imágenes a nivel de vecindario oblicuas son capturadas con suficiente traslape de tal manera que cada área de interés es cubierta

típicamente por al menos dos imágenes oblicuas de cada dirección de compás capturada, y de tal manera que las direcciones de compás opuestas proporcionan un 100% de traslape una con la otra. Aproximadamente cien (100) imágenes de área oblicua son capturadas por sector.

Deberá notarse particularmente que las imágenes oblicuas a nivel de comunidad y/o de vecindario de las cuatro direcciones de compás asegura que cada punto en la imagen aparecerá en el primer plano o una posición inferior de al menos una de las imágenes oblicuas capturadas, en donde la distancia de muestra terrestre es la más baja y el detalle de la imagen es el mayor.

En la modalidad mostrada, el sistema de captura de imágenes y geolocalización 30 incluye un giroscopio, un compás y un altímetro. Sin embargo, deberá entenderse que el sistema de captura de imágenes y geolocalización de la presente invención puede configurarse alternativamente, tal como, por ejemplo, derivar y/o calcular altitud, inclinación, balanceo y guiñada y rumbo del compás de las señales/datos de GPS y INU, haciendo que sea innecesario uno o más del giroscopio, compás y altímetro.

En la modalidad mostrada, los dispositivos de captura de imágenes están a un ángulo igual de declinación en relación con un plano horizontal. Sin embargo, se entenderá que los ángulos de declinación de los dispositivos de captura de imágenes no tienen que ser iguales.

En la modalidad mostrada, el sistema de cómputo de captura de imágenes ejecuta el software de adquisición de imágenes y datos que emite una señal de captura de imágenes común o sencilla a los dispositivos de captura de imágenes para ocasionar con ello que los dispositivos adquieran o capturen una imagen. Sin embargo, se entenderá que la presente invención puede configurarse alternativamente para provocar por separado que los dispositivos de captura de imágenes capturen imágenes en instantes diferentes y/o a intervalos diferentes.

En la modalidad mostrada, el método de la presente invención captura imágenes oblicuas para proporcionar doble cobertura de una área de interés de las trayectorias/perspectivas que están substancialmente opuestas una de la otra, es decir 180° (ciento ochenta grados) una en relación con la otra. Sin embargo, se entenderá que el método de la presente invención puede configurarse alternativamente para proporcionar doble cobertura de las trayectorias/perspectivas que generalmente y/o substancialmente son perpendiculares una en relación con la otra.

Mientras que la presente invención se ha descrito teniendo un diseño preferido, la invención puede modificarse adicionalmente dentro del espíritu y alcance de la presente descripción. Esta descripción pretende por lo tanto abarcar cualquier equivalente de las estructuras y elementos aquí

descritos. Adicionalmente, la presente descripción pretende abarcar cualquier variación, uso, o adaptaciones de la presente invención que emplee los principios generales aquí descritos. Además, esta descripción pretende abarcar cualquier alejamiento del tema descrito que acompaña al conocimiento o práctica acostumbrada en la técnica pertinente y que cae dentro de los límites de las reivindicaciones anexas.

Se hace constar que con relación a esta fecha, el mejor método conocido por la solicitante para llevar a la práctica la citada invención, es el que resulta claro de la presente descripción de la invención.

REIVINDICACIONES

Habiéndose descrito la invención como antecede se reclama como propiedad lo contenido en las siguientes reivindicaciones:

1. Un sistema para la captura de imágenes y la geolocalización de datos que corresponden a las mismas, caracterizado porque comprende:

un dispositivo de captura de imágenes, el dispositivo de captura de imágenes captura imágenes oblicuas en eventos de captura de imágenes, el dispositivo de captura de imágenes emite señales de datos de imágenes que corresponden a imágenes capturadas;

al menos un dispositivo de geolocalización, cada uno de los al menos un dispositivo de geolocalización emite al menos una señal de geolocalización correspondiente, cada una de las al menos una señal de geolocalización es indicativa al menos en parte de una geolocalización de ese dispositivo de captura de imágenes durante cada evento de captura de imágenes; y

un sistema de cómputo que recibe y almacena esas señales de imágenes y datos y la al menos una señal de geolocalización; y

software de adquisición de imágenes y datos que leen esas señales de imágenes y datos y la al menos una señal de

geolocalización, el software asocia cada una de las señales de imágenes y datos con al menos una señal de geolocalización correspondiente para cada evento de captura de imágenes.

2. El sistema de conformidad con la reivindicación 1, caracterizado porque el al menos un dispositivo de geolocalización y la al menos una señal de geolocalización comprende respectivamente uno de los siguientes:

un reloj que emite al sistema de cómputo de captura de imágenes señales de datos de tiempo indicativas de un tiempo de cada evento de captura de imágenes;

un receptor de sistema de posicionamiento global (GPS) que recibe señales del sistema de posicionamiento global y que emite al sistema de cómputo de captura de imágenes señales de datos de localización indicativas de una longitud y latitud del dispositivo de captura de imágenes en cada evento de captura de imágenes;

una unidad de navegación inercial (INU) que emite al sistema de cómputo de captura de imágenes señales de datos de velocidad indicativas de una velocidad del dispositivo de captura de imágenes en cada evento de captura de imágenes;

un giroscopio que emite al sistema de cómputo de captura de imágenes una señal de inclinación, una señal de balanceo, y una señal de guiñada indicativas respectivamente de una inclinación, un balanceo y una guiñada del dispositivo de captura de imágenes en cada evento de captura de imágenes;

un compás que emite al sistema de cómputo de captura de imágenes señales de datos de rumbo indicativas de un rumbo del dispositivo de captura de imágenes en cada evento de captura de imágenes; y

un altímetro que emite al sistema de cómputo de captura de imágenes señales de datos indicativas de una altitud del dispositivo de captura de imágenes en cada evento de captura de imágenes.

3. El sistema de conformidad con la reivindicación 1, caracterizado porque el al menos un dispositivo de geolocalización y la al menos una señal de geolocalización comprenden respectivamente:

un reloj que emite al sistema de cómputo de captura de imágenes señales de datos de tiempo indicativas de un tiempo de cada evento de captura de imágenes;

un receptor de sistema de posicionamiento global (GPS) que recibe señales del sistema de posicionamiento global y que emite al sistema de cómputo de captura de imágenes señales de datos de localización indicativas de una longitud y latitud del dispositivo de captura de imágenes en cada evento de captura de imágenes;

una unidad de navegación inercial (INU) que emite al sistema de cómputo de captura de imágenes señales de datos de velocidad indicativas de una velocidad del dispositivo de captura de imágenes en cada uno de los eventos de captura de imágenes;

un giroscopio que emite al sistema de cómputo de captura de imágenes una señal de inclinación, una señal de balanceo, y una señal de guiñada indicativas respectivamente de una inclinación, un balanceo y una guiñada del dispositivo de captura de imágenes en cada evento de captura de imágenes;

un compás que emite al sistema de cómputo de captura de imágenes señales de datos de rumbo indicativas de un rumbo del dispositivo de captura de imágenes en cada evento de captura de imágenes; y

un altímetro que emite al sistema de cómputo de captura de imágenes señales de datos indicativas de una altitud del dispositivo de captura de imágenes en cada evento de captura de imágenes.

4. El sistema de conformidad con la reivindicación 1, caracterizado porque adicionalmente comprende datos de corrección indicativos de características del dispositivo de captura de imágenes incluyendo longitud focal, tamaño de sensor, distorsión radial, desviación del punto principal y alineamiento, el software de adquisición de imágenes y datos utiliza esos datos de corrección para corregir imágenes capturadas.

5. El sistema de conformidad con la reivindicación 1, caracterizado porque adicionalmente comprende un archivo de datos de salida creado por el software de adquisición de imágenes y datos, el archivo de datos de salida incluye una

pluralidad de archivos de imagen y datos de posición que corresponden a cada una de esa pluralidad de archivos de imagen.

6. El sistema de conformidad con la reivindicación 1, caracterizado porque adicionalmente comprende una plataforma que transporta al dispositivo de captura de imágenes a una distancia predeterminada sobre una superficie de interés.

7. Un sistema computarizado para visualizar, geolocalizar, y hacer mediciones con base en imágenes oblicuas, caracterizado porque comprende:

un sistema de cómputo que tiene una memoria;

un archivo de imágenes y datos accesible por ese sistema e incluyendo una pluralidad de archivos de imágenes que corresponden a una pluralidad de imágenes oblicuas capturadas, el archivo de imágenes y datos adicionalmente incluyendo datos de posición que corresponden a esa pluralidad de archivos de imágenes;

software de visualización y análisis ejecutado por el sistema para la lectura de esos archivos de imágenes y datos y visualizando al menos una parte de las imágenes oblicuas capturadas como una imagen visualizada, el software recupera esos datos de posición de uno o más puntos seleccionados en esa imagen visualizada, el software calcula una distancia de separación entre cualquiera de dos o más puntos seleccionados en esa imagen visualizada.

8. El sistema de conformidad con la reivindicación 7, caracterizado porque adicionalmente comprende un archivo de datos del plano terrestre que representa un plano terrestre teselado, el archivo de datos del plano terrestre es accesible por medio del sistema de cómputo, el archivo de plano terrestre representa un plano terrestre teselado que se aproxima bastante al menos a una porción del terreno representado en esas imágenes oblicuas capturadas.

9. El sistema de conformidad con la reivindicación 8, caracterizado porque el plano terrestre teselado adicionalmente comprende una pluralidad de facetas interconectadas, cada una de esa pluralidad de facetas tiene una respectiva inclinación y pendiente.

10. El sistema de conformidad con la reivindicación 9, caracterizado porque el archivo de datos del plano terrestre comprende una pluralidad de vértices, cada uno de esa pluralidad de vértices tiene elevaciones respectivas y que definen esquinas de esa pluralidad de facetas interconectadas, dos de esa pluralidad de vértices están compartidas por cada una de esas facetas interconectadas.

11. El sistema de conformidad con la reivindicación 10, caracterizado porque el software de visualización y análisis de imágenes identifica cuál de esa pluralidad de facetas corresponde a un punto seleccionado en esa imagen visualizada, y calcula una elevación de ese punto

seleccionado dependiente al menos en parte de la elevación de los vértices de la faceta que corresponden al punto seleccionado, el software de visualización y análisis de imágenes utiliza esa elevación calculada para calcular la distancia de separación entre el punto seleccionado y uno más puntos seleccionados adicionales.

12. El sistema de conformidad con la reivindicación 11, caracterizado porque el software de visualización y análisis de imágenes calcula una altura de un objeto en la imagen visualizada calculando la distancia de separación entre dos o más puntos seleccionados.

13. El sistema de conformidad con la reivindicación 8, caracterizado porque el plano terrestre teselado es uno superpuesto y ajustado a esa imagen visualizada.

14. El sistema de conformidad con la reivindicación 7, caracterizado porque el software de visualización y análisis visualizada incluye modos de medición seleccionables por el usuario accesibles a través de al menos uno de menús desplegables, barras de herramientas y comandos de teclado.

15. El sistema de conformidad con la reivindicación 7, caracterizado porque cada una de las imágenes fueron capturadas por un dispositivo de captura de imágenes y en eventos de captura de imágenes respectivos, caracterizado porque los datos de posición del archivo de imágenes y datos incluye:

datos de tiempo que representan el tiempo de cada evento de captura de imágenes;

datos de localización que representan la localización del dispositivo de captura de imágenes en cada evento de captura de imágenes;

datos de orientación que representan la orientación del dispositivo de captura de imágenes en cada evento de captura de imágenes;

datos de corrección que representan factores de corrección para el dispositivo de captura de imágenes; y

datos de elevación que representan una elevación promedio de la superficie capturada por el dispositivo de captura de imágenes.

16. El sistema de conformidad con la reivindicación 15, caracterizado porque los datos de localización incluyen latitud, longitud, y altitud del aparato de captura de imágenes en cada evento de captura de imágenes.

17. El sistema de conformidad con la reivindicación 15, caracterizado porque los datos de orientación incluyen balanceo, inclinación, guiñada y rumbo del dispositivo de captura de imágenes en cada evento de captura de imágenes.

18. El conjunto de datos de conformidad con la reivindicación 15, caracterizado porque el dispositivo de captura de imágenes es una cámara y los datos de corrección incluyen al menos uno de longitud focal, tamaño de sensor,

relación de aspecto, desviación del punto principal, distorsión, e inclinación de píxeles.

19. Un método computarizado para hacer mediciones en una imagen oblicua visualizada, caracterizado porque comprende:

seleccionar con un dispositivo de entrada un punto inicial y un punto final en la imagen visualizada;

recuperar de un archivo de datos, datos de posición que corresponden al punto inicial y al punto final;

referenciar un archivo de datos de plano terrestre que corresponde a un plano terrestre teselado que tiene una pluralidad de facetas, cada una de las facetas tiene una inclinación y pendiente respectiva, el plano terrestre teselado coincide bastante con un terreno de esa imagen oblicua visualizada;

conectar los puntos iniciales y finales con segmentos de líneas, los segmentos de líneas se conforman con la inclinación y pendiente de las facetas para seguir de esta manera al terreno; y

calcular la distancia lineal a lo largo de esos segmentos de línea entre los puntos inicial y final de esta manera tomando en cuenta la inclinación y pendiente de las facetas.

20. El método de conformidad con la reivindicación 19, caracterizado porque el plano terrestre teselado se superpone a la imagen oblicua visualizada.

21. El método de conformidad con la reivindicación 19, caracterizado porque adicionalmente comprende las etapas de:

seleccionar con un dispositivo de entrada uno o más puntos intermedios en la imagen visualizada;

recuperar del archivo de datos, datos de posición que corresponden a uno o más puntos intermedios; y

conectar uno con otro puntos intermedios adyacentes, y conectar los puntos inicial y final a puntos intermedios adyacentes, con segmentos de línea, los segmentos de línea se conforman a la inclinación y pendiente de las facetas para así seguir el terreno; y

calcular la distancia a lo largo de esos segmentos de línea entre los puntos inicial y final.

22. El método de conformidad con la reivindicación 19, caracterizado porque cada una de la pluralidad de facetas corresponde a áreas iguales de la imagen oblicua visualizada.

23. El método de conformidad con la reivindicación 19, caracterizado porque cada una de la pluralidad de facetas incluye un número igual de píxeles de la imagen oblicua visualizada.

24. Un método computarizado para hacer mediciones de una imagen oblicua visualizada en un sistema de cómputo, al menos un dispositivo de entrada está conectado a ese sistema de cómputo, un archivo de datos de imágenes es accesible por medio del sistema de cómputo, el archivo de datos de imágenes

incluye imágenes capturadas y datos de posición que corresponden a las mismas, caracterizado porque el método computarizado comprende:

colocar el sistema de cómputo en un modo deseado de una pluralidad de modos de medición, el modo de medición deseado se configura para calcular una medición deseada;

seleccionar un punto inicial en la imagen visualizada;

recuperar los datos de posición que corresponden al punto inicial;

seleccionar un punto final en la imagen visualizada;

recuperar los datos de posición que corresponden al punto final; y

calcular la medición deseada dependiente al menos en parte de los datos de posición de esos puntos inicial y final.

25. El método de conformidad con la reivindicación 24, caracterizado porque adicionalmente comprende las etapas de:

seleccionar uno o más puntos intermedios en la imagen visualizada; y

recuperar los datos de posición que corresponden a los puntos intermedios.

26. El método de conformidad con la reivindicación 24, caracterizado porque la pluralidad de modos de medición comprende un modo de medición de distancia que calcula una distancia entre dos o más puntos seleccionados, un modo de

medición de altura que calcula una diferencia de altura entre dos o más puntos seleccionados, un modo de medición de elevación relativa que calcula la diferencia en elevación de dos o más puntos seleccionados, y un modo de medición de área que calcula el área abarcada por al menos tres puntos.

27. Un método de captura de imágenes oblicuas de un área de interés con un dispositivo de captura de imágenes portado por una plataforma, cada imagen oblicua capturada en un evento de captura de imagen respectivo, caracterizado porque el método comprende:

subdividir el área de interés en una pluralidad de sectores;

guiar la plataforma a lo largo de una primera trayectoria para así apuntar a uno o más sectores objetivo con el dispositivo de captura de imágenes;

capturar con el dispositivo de captura de imágenes una o más imágenes oblicuas para así cubrir una totalidad de cada sector objetivo en imágenes oblicuas capturadas de una primera perspectiva;

guiar la plataforma a lo largo de una segunda trayectoria para así apuntar a esos sectores objetivo;

capturar con el dispositivo de captura de imágenes una o más imágenes oblicuas para así cubrir

una totalidad de cada sector objetivo en imágenes oblicuas capturadas de una segunda perspectiva;

repetir las etapas de guiar y capturar a lo largo de trayectorias substancialmente paralelas y espaciadas de la primera y segunda trayectorias y capturar una o más imágenes oblicuas para cubrir así una totalidad de cada uno de la pluralidad de sectores en imágenes oblicuas capturadas de cada una de la primera y segunda perspectivas; y

registrar datos de posición indicativos de una geolocalización del dispositivo de captura de imágenes en cada evento de captura de imágenes.

28. El método de conformidad con la reivindicación 27, caracterizado porque la segunda trayectoria es substancialmente paralela en relación a 180° (ciento ochenta grados) de la primera trayectoria;

29. El método de conformidad con la reivindicación 28, caracterizado porque la segunda trayectoria está también espaciada de la primera trayectoria.

30. El método de conformidad con la reivindicación 27, caracterizado porque adicionalmente comprende las etapas de:

guiar la plataforma a lo largo de una tercera

trayectoria para así apuntar a uno o más sectores objetivo con el dispositivo de captura de imágenes, siendo la tercera trayectoria substancialmente perpendicular a la primera y segunda trayectorias;

capturar con el dispositivo de captura de imágenes una o más imágenes oblicuas para así cubrir una totalidad de cada sector objetivo en imágenes oblicuas capturadas de una tercera perspectiva; y

repetir las etapas de guiar y capturar a lo largo de trayectorias substancialmente paralelas y espaciadas de la tercera trayectoria y capturar una o más imágenes oblicuas para cubrir así una totalidad de cada uno de la pluralidad de sectores en imágenes oblicuas capturadas de esa tercera perspectiva.

31. El método de conformidad con la reivindicación 30, caracterizado porque adicionalmente comprende las etapas de:

guiar la plataforma a lo largo de una cuarta trayectoria para así apuntar a uno o más sectores objetivo con el dispositivo de captura de imágenes, siendo la cuarta trayectoria substancialmente paralela con la tercera trayectoria y 180° (ciento ochenta grados) de esa tercera trayectoria;

capturar con el dispositivo de captura de imágenes una o más imágenes oblicuas para así cubrir una totalidad de cada sector objetivo en imágenes oblicuas capturadas de una cuarta

perspectiva; y

repetir las etapas de guiar y capturar a lo largo de trayectorias substancialmente paralelas y espaciadas de la cuarta trayectoria y capturar una o más imágenes oblicuas para cubrir así una totalidad de cada uno de la pluralidad de sectores en imágenes oblicuas capturadas de esa cuarta perspectiva.

32. El método de conformidad con la reivindicación 31, caracterizado porque la cuarta trayectoria está también espaciada de la tercera trayectoria.

RESUMEN DE LA INVENCIÓN

Un sistema computarizado para visualizar, geolocalizar, y hacer mediciones de imágenes oblicuas capturadas incluye un archivo de datos accesible por medio del sistema de cómputo. El archivo de datos incluye una pluralidad de archivos de imágenes que corresponden a una pluralidad de imágenes oblicuas capturadas, y datos de posición que corresponden a las imágenes. Se ejecuta un software de visualización y análisis de imágenes a través del sistema para leer los archivos de datos y visualizar al menos una parte de las imágenes oblicuas capturadas. El software recupera los datos de posición para uno o más puntos seleccionados por el usuario en la imagen visualizada, y calcula una distancia de separación entre cualquiera de dos o más puntos elegidos. El cálculo de la distancia de separación la selecciona el usuario para determinar varios parámetros incluyendo la distancia lineal, área abarcada, elevación relativa, y diferencia de altura entre puntos seleccionados.

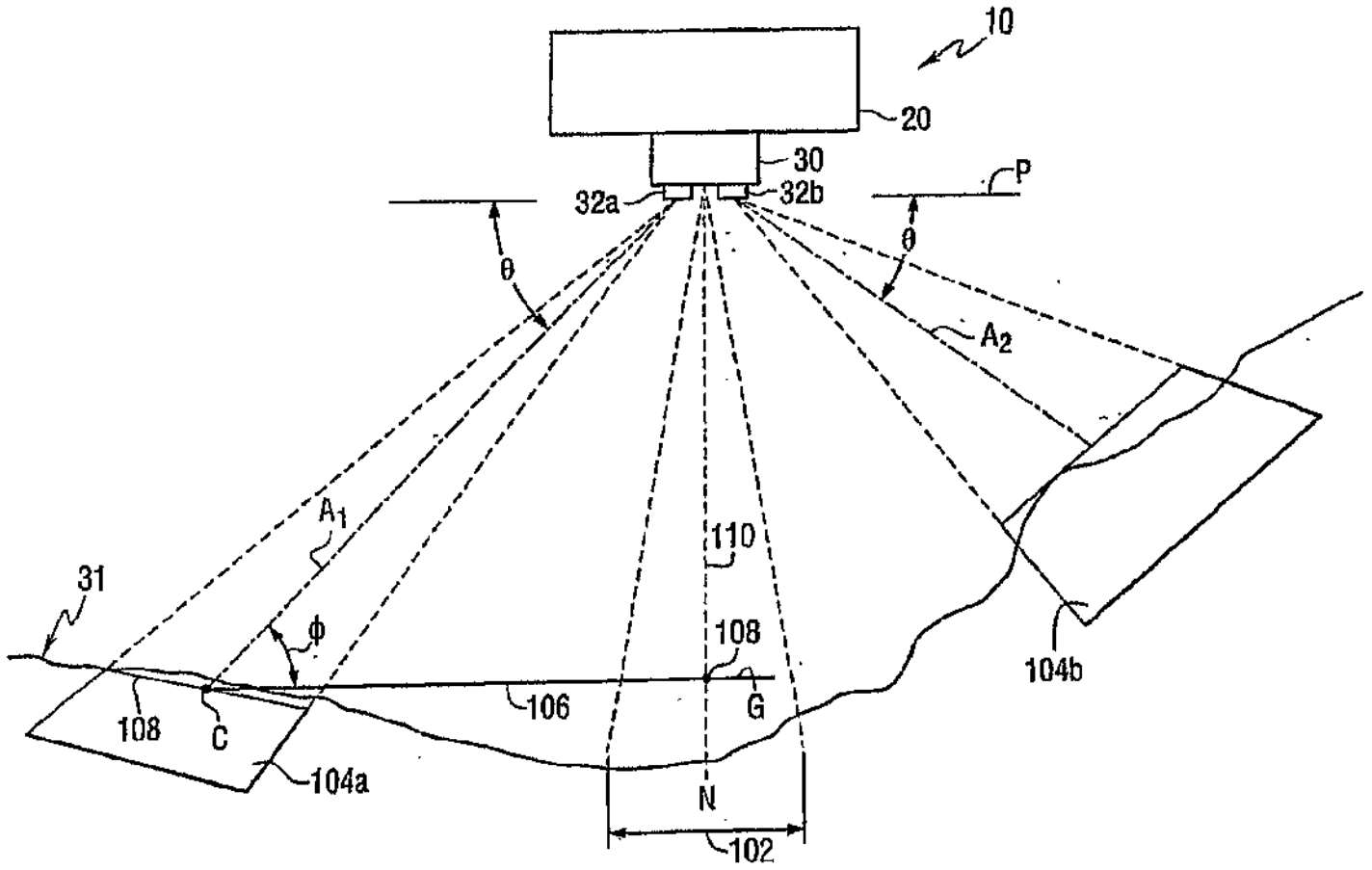


FIG. 1

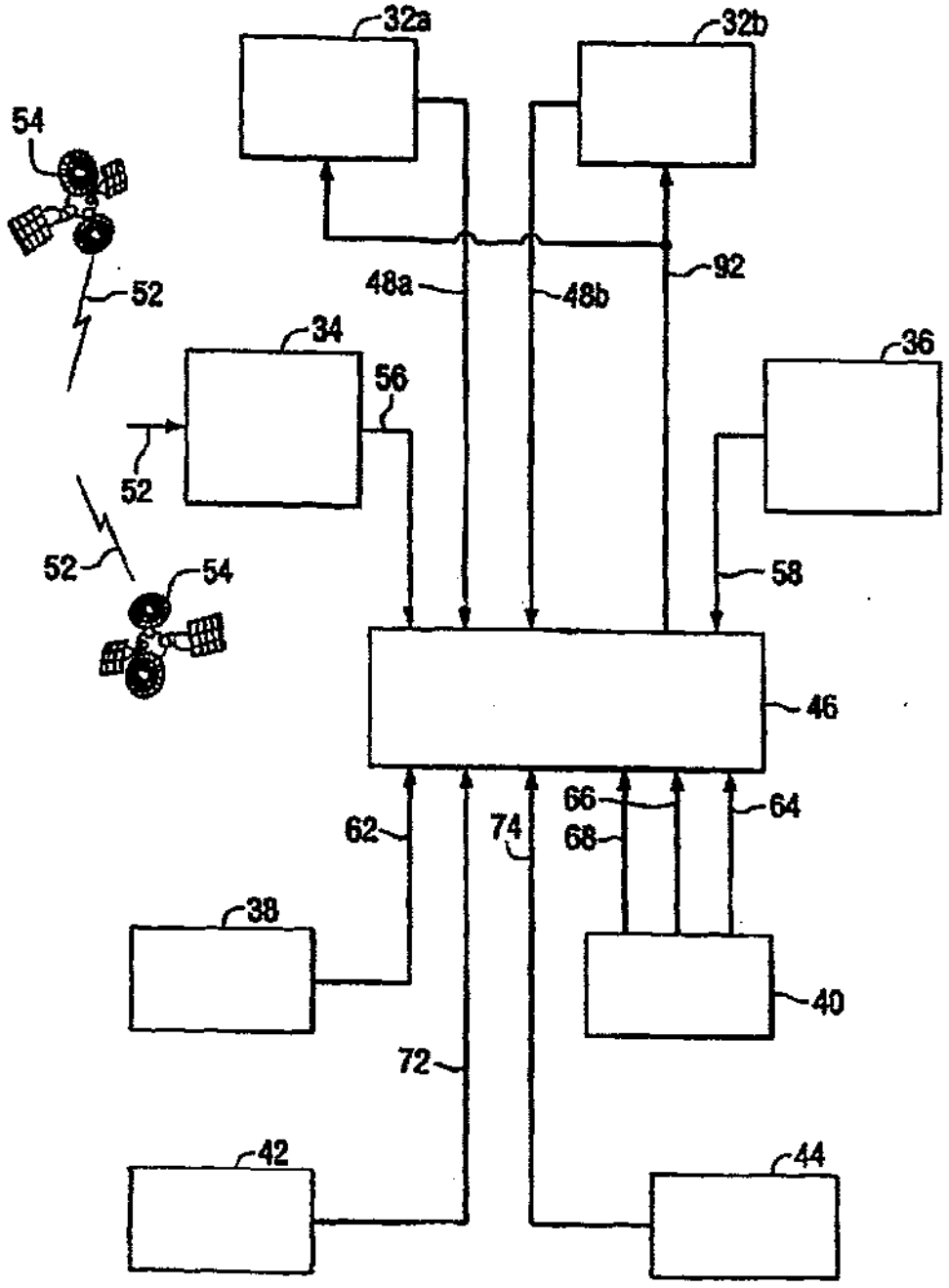

32a
32b
54
52
48a
48b
92
34
56
36
52
52
54
58
46
62
74
66
68
64
38
40
72
42
44

FIG. 2

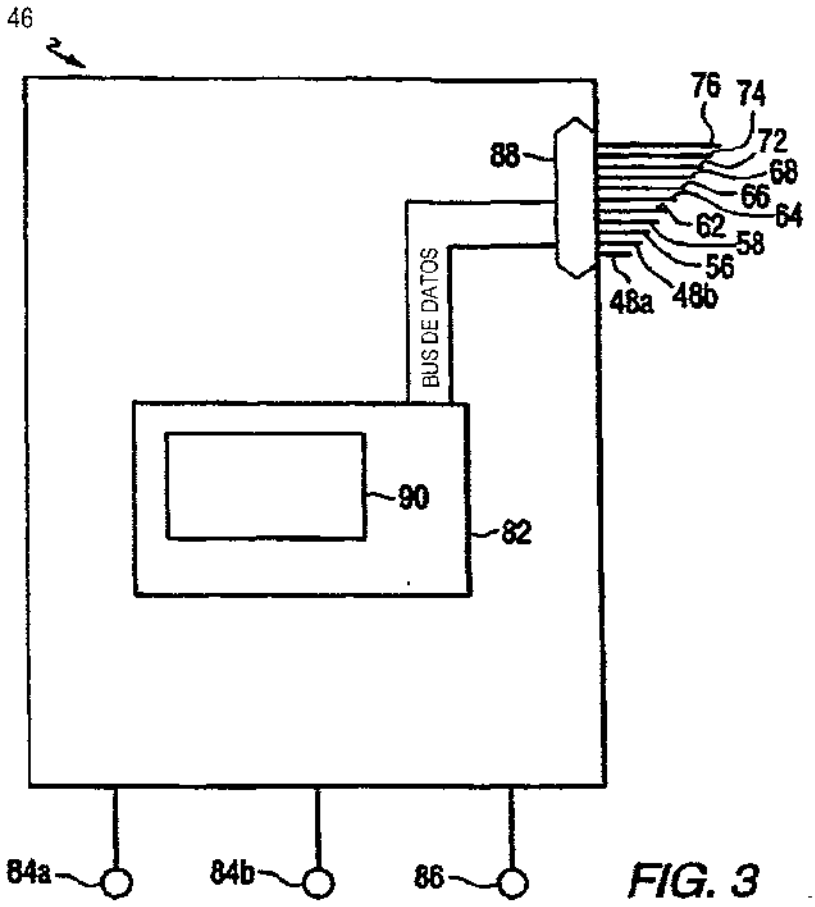

46
76
74
72
68
66
64
62
58
56
88
48a
48b
BUS DE DATOS
90
82
84a
84b
86

FIG. 3

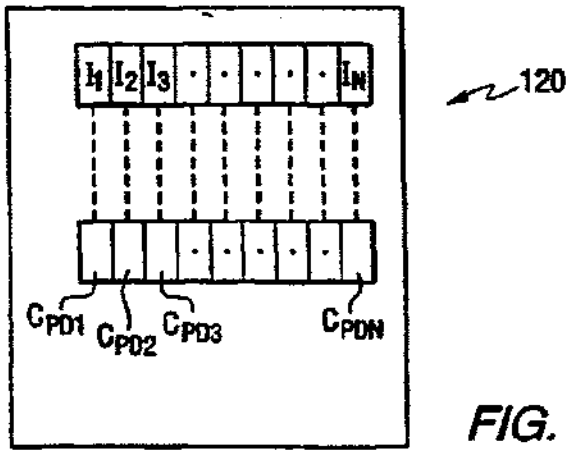

I1 I2 I3 IN
120
CPD1 CPD2 CPD3 CPDN

FIG. 4

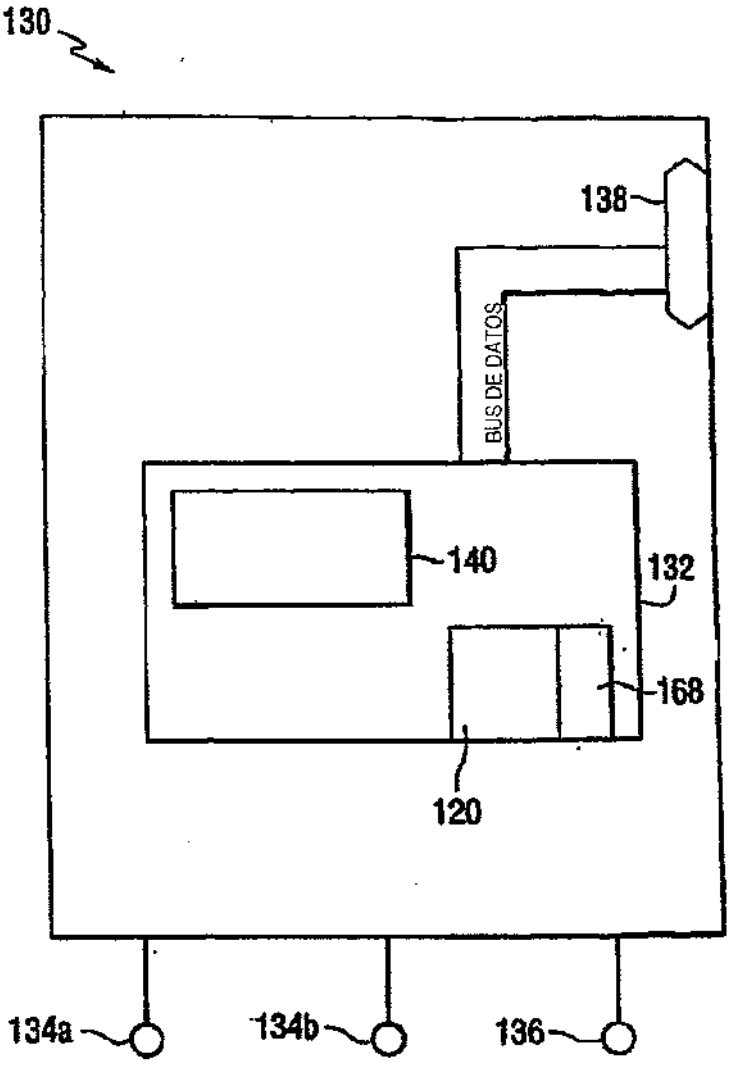


FIG. 5

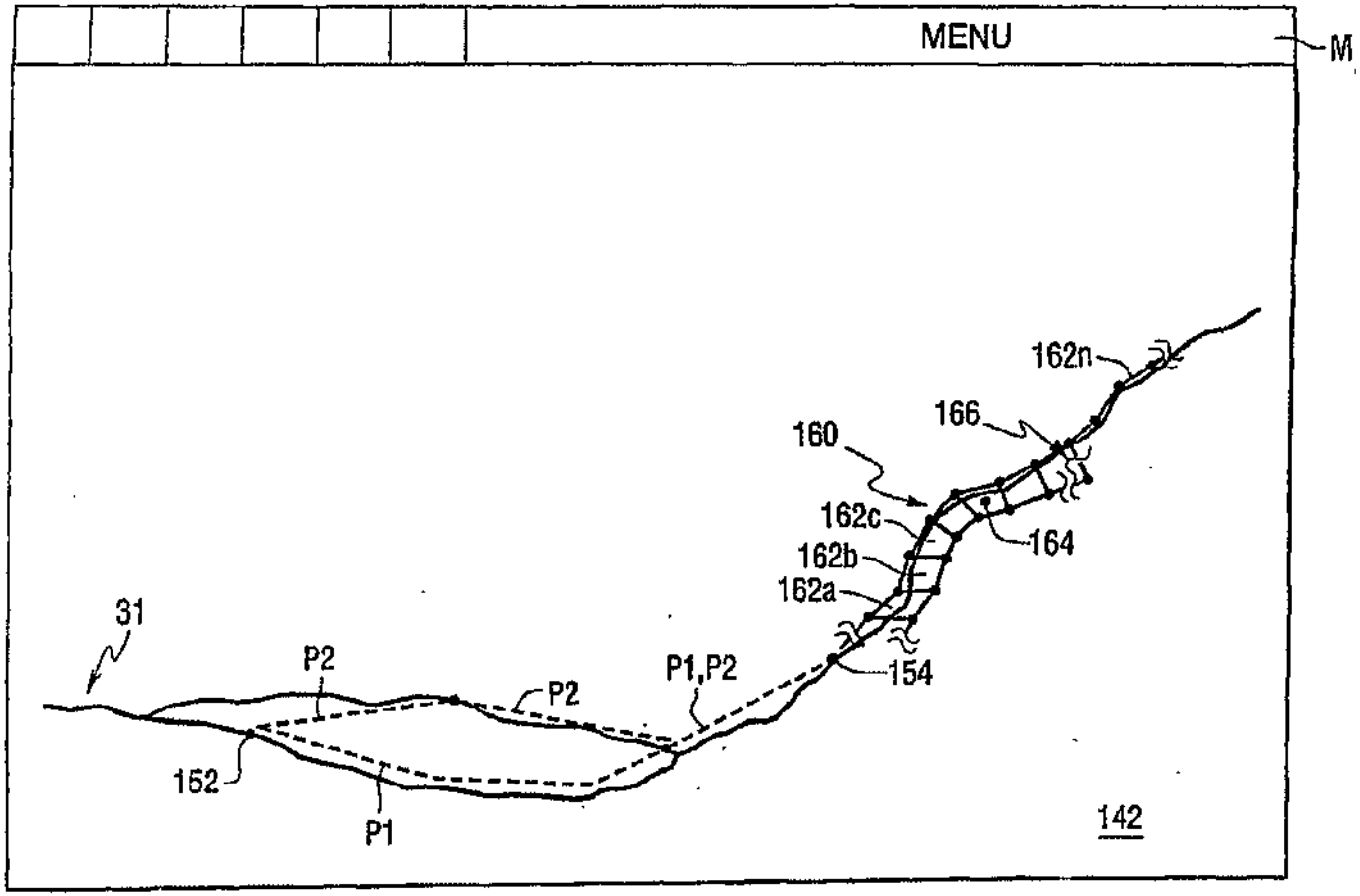

MENU
M
162n
166
160
162c
164
162b
162a
154
31
P2
P2
P1,P2
152
P1
142

FIG. 6

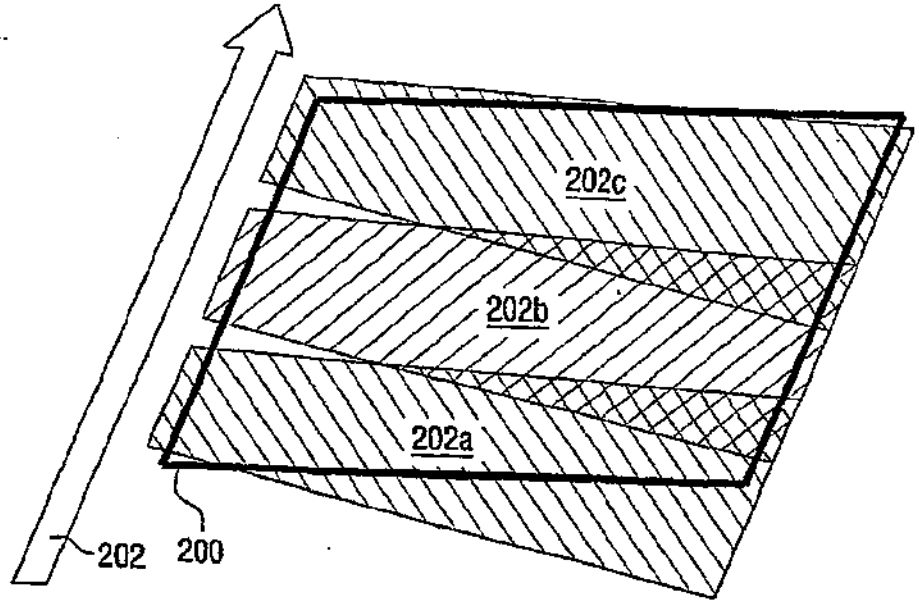


FIG. 7

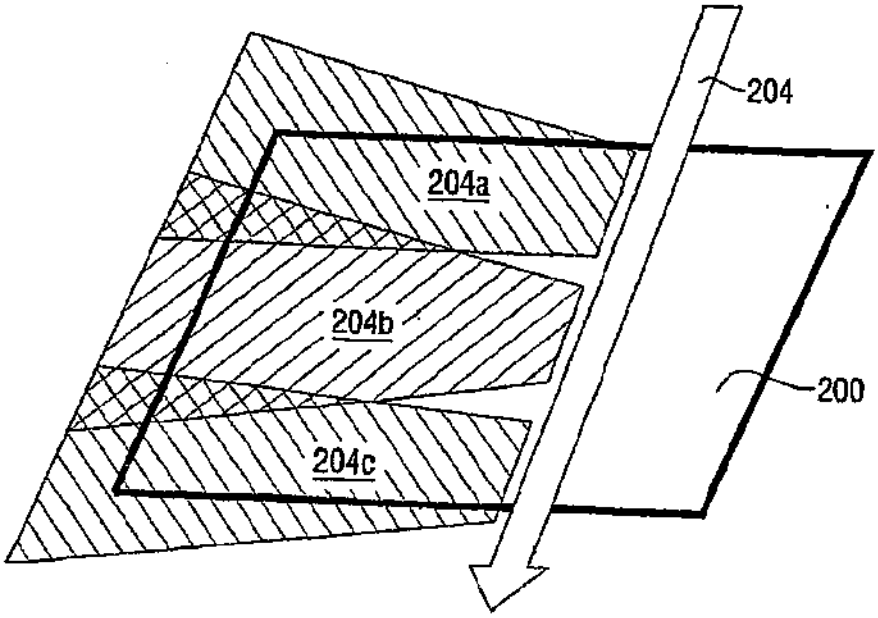


FIG. 8

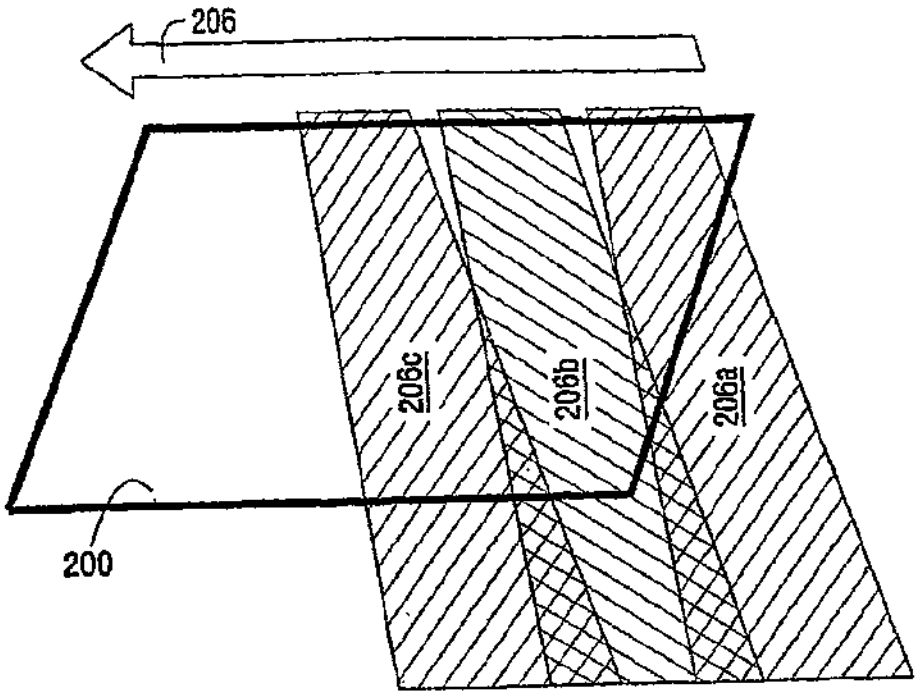


FIG. 9

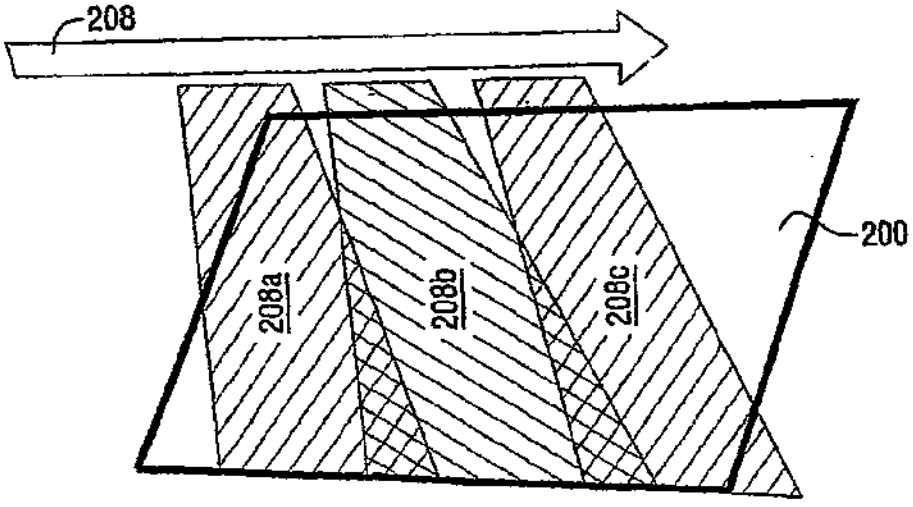


FIG. 10

Deutsches Patent- und Markenamt

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Bibliographic data

AT000000331204E document (Pages: 0)

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BIBLIOGRAPHIC DATA DOCUMENT ATPREPUBLISHED (PAGE 0)

Criterion	Field	Content
Title	TI	[DE] METHOD AND APPARATUS FOR DETERMINING, geolocation SURVEYING AND BIAS recorded images
Applicant / Owner	PA	Pictometry INTERNAT CORP., U.S.
Inventor	IN	GIUFFRIDA FRANK D, U.S. GRAY ROBERT L, U.S. MONDELLO CHARLES, U.S. SCHULTZ STEPHEN L, U.S.
Joined	AD	07.11.2003
Application number	AN	03025702
Application Country	AC	AT
Released	PUB	15.07.2006
Priority	PRC PRN PRD	U.S. 42527502 20,021,108
IPC main class	ICM	G01C 11/02
IPC -coset	ICS	
IPC additional class	ICA	
IPC index class	ICI	
MCD main class	MCM	
MCD-coset	MCS	G01C 11/02 (2006.01) G06T 17/05 (2011.01)
MCD additional class	MCA	
Abstract	AB	
Correction information	KORRINF	
And of patent documents identified in research	CT	
And of patent documents, the applicant named	CT	
Contrary held non-patent literature identified in research	CTNP	
Contrary held non-patent literature, the applicant named	CTNP	
Test substance- IPC	ICP	

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 May 2004 (27.05.2004)

PCT

(10) International Publication Number
WO 2004/044692 A2

(51) International Patent Classification[7]: G06F

(21) International Application Number:
PCT/US2003/035528

(22) International Filing Date:
7 November 2003 (07.11.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/425,275 8 November 2002 (08.11.2002) US

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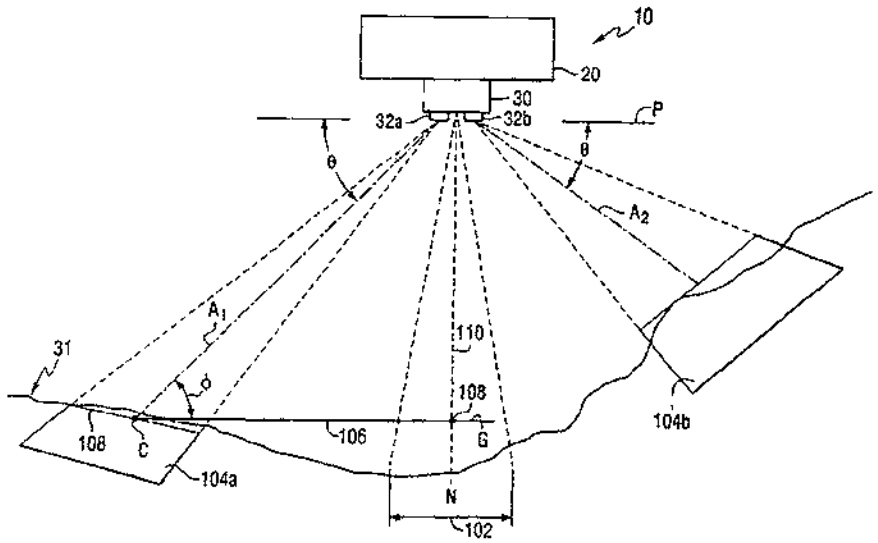
(81) Designated States (*national*): AE, AG, AL, AM, AU, AZ, BA, BB, BR, BY, BZ, CA, CN, CO, CR, CU, DK, DM, DZ, EC, EE, ES, FI, GD, GE, GH, GM, HR, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, RU, SC, SD, SG, SL, SY, TJ, TM, TN, TR, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM



(57) Abstract: A computerized system for displaying, geolocating, and taking measurements from captured oblique images includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area encompassed within, relative elevation of, and height difference between selected points.

WO 2004/044692 A2

OBLIQUE GEOLOCATION AND MEASUREMENT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/425,275, filed November 8, 2002.

TECHNICAL FIELD

The present invention relates to photogrammetry. More particularly, the present invention relates to a method and apparatus for capturing oblique images and for measuring the objects and distances between the objects depicted therein.

BACKGROUND

Photogrammetry is the science of making measurements of and between objects depicted within photographs, especially aerial photographs. Generally, photogrammetry involves taking images of terrestrial features and deriving data therefrom, such as, for example, data indicating relative distances between and sizes of objects within the images. Photogrammetry may also involve coupling the photographs with other data, such as data representative of latitude and longitude. In effect, the image is overlaid and conformed to a particular spatial coordinate system.

Conventional photogrammetry involves the capture and/or acquisition of orthogonal images. The image-capturing device, such as a camera or sensor, is

orthogonal images. The image-capturing device, such as a camera or sensor, is carried by a vehicle or platform, such as an airplane or satellite, and is aimed at a nadir point that is directly below and/or vertically downward from that platform. The point or pixel in the image that corresponds to the nadir point is the only point/pixel that is truly orthogonal to the image-capturing device. All other points or pixels in the image are actually oblique relative to the image-capturing device. As the points or pixels become increasingly distant from the nadir point they become increasingly oblique relative to the image-capturing device and the ground sample distance (i.e., the surface area corresponding to or covered by each pixel) also increases. Such obliqueness in an orthogonal image causes features in the image to be distorted, especially images relatively distant from the nadir point.

Such distortion is removed, or compensated for, by the process of ortho-rectification which, in essence, removes the obliqueness from the orthogonal image by fitting or warping each pixel of an orthogonal image onto an orthometric grid or coordinate system. The process of ortho-rectification creates an image wherein all pixels have the same ground sample distance and are oriented to the north. Thus, any point on an ortho-rectified image can be located using an X, Y coordinate system and, so long as the image scale is known, the length and width of terrestrial features as well as the relative distance between those features can be calculated.

Although the process of ortho-rectification compensates to a degree for oblique distortions in an orthogonal image, it introduces other undesirable distortions and/or

inaccuracies in the ortho-rectified orthogonal image. Objects depicted in ortho-rectified orthogonal images may be difficult to recognize and/or identify since most observers are not accustomed to viewing objects, particularly terrestrial features, from above. To an untrained observer an ortho-rectified image has a number of distortions. Roads that are actually straight appear curved and buildings may appear to tilt. Further, ortho-rectified images contain substantially no information as to the height of terrestrial features. The interpretation and analysis of orthogonal and/or ortho-rectfified orthogonal images is typically performed by highly-trained analysts whom have undergone years of specialized training and experience in order to identify objects and terrestrial features in such images.

Thus, although orthogonal and ortho-rectified images are useful in photogrammetry, they lack information as to the height of features depicted therein and require highly-trained analysts to interpret detail from what the images depict.

Oblique images are images that are captured with the image-capturing device aimed or pointed generally to the side of and downward from the platform that carries the image-capturing device. Oblique images, unlike orthogonal images, display the sides of terrestrial features, such as houses, buildings and/or mountains, as well as the tops thereof. Thus, viewing an oblique image is more natural and intuitive than viewing an orthogonal or ortho-rectified image, and even casual observers are able to recognize and interpret terrestrial features and other objects depicted in oblique images. Each pixel in the foreground of an oblique image corresponds to a relatively small area of the

surface or object depicted (i.e., each foreground pixel has a relatively small ground sample distance) whereas each pixel in the background corresponds to a relatively large area of the surface or object depicted (i.e., each background pixel has a relatively large ground sample distance). Oblique images capture a generally trapezoidal area or view of the subject surface or object, with the foreground of the trapezoid having a substantially smaller ground sample distance (i.e., a higher resolution) than the background of the trapezoid.

Oblique images are considered to be of little or no use in photogrammetry. The conventional approach of forcing the variously-sized foreground and background pixels of an oblique image into a uniform size to thereby warp the image onto a coordinate system dramatically distorts the oblique image and thereby renders identification of objects and the taking of measurements of objects depicted therein a laborious and inaccurate task. Correcting for terrain displacement within an oblique image by using an elevation model further distorts the images thereby increasing the difficulty with which measurements can be made and reducing the accuracy of any such measurements.

Thus, although oblique images are considered as being of little or no use in photogrammetry, they are easily interpreted and contain information as to the height of features depicted therein.

Therefore, what is needed in the art is a method and apparatus for photogrammetry that enable geo-location and accurate measurements within oblique

images.

Moreover, what is needed in the art is a method and apparatus for photogrammetry that enable the measurement of heights and relative heights of objects within an image.

Furthermore, what is needed in the art is a method and apparatus for photogrammetry that utilizes more intuitive and natural images.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for capturing, displaying, and making measurements of objects and distances between objects depicted within oblique images.

The present invention comprises, in one form thereof, a computerized system for displaying, geolocating, and taking measurements from captured oblique images. The system includes a data file accessible by the computer system. The data file includes a plurality of image files corresponding to a plurality of captured oblique images, and positional data corresponding to the images. Image display and analysis software is executed by the system for reading the data file and displaying at least a portion of the captured oblique images. The software retrieves the positional data for one or more user-selected points on the displayed image, and calculates a separation distance between any two or more selected points. The separation distance calculation is user-selectable to determine various parameters including linear distance between, area

encompassed within, relative elevation of, and height difference between selected points.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be more completely understood by reference to the following description of one embodiment of the invention when read in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates one embodiment of a platform or vehicle carrying an image-capturing system of the present invention, and shows exemplary orthogonal and oblique images taken thereby;

FIG. 2 is a diagrammatic view of the image-capturing system of FIG. 1;

FIG. 3 is a block diagram of the image-capturing computer system of Fig. 2;

FIG. 4 is a representation of an exemplary output data file of the image-capturing system of Fig. 1;

FIG. 5 is a block diagram of one embodiment of an image display and measurement computer system of the present invention for displaying and taking measurements of and between objects depicted in the images captured by the image-capturing system of Fig. 1;

FIG. 6 depicts an exemplary image displayed on the system of Fig. 5, and illustrates one embodiment of the method of the present invention for the measurement

of and between objects depicted in such an image;

FIGS. 7 and 8 illustrate one embodiment of a method for capturing oblique images of the present invention;

FIGS. 9 and 10 illustrate a second embodiment of a method for capturing oblique images of the present invention.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate one preferred embodiment of the invention, in one form, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to Fig. 1, one embodiment of an apparatus for capturing and geolocating oblique images of the present invention is shown. Apparatus 10 includes a platform or vehicle 20 that carries image-capturing and geolocating system 30.

Platform 20, such as, for example, an airplane, space shuttle, rocket, satellite, or any other suitable vehicle, carries image-capturing system 30 over a predefined area of and at one or more predetermined altitudes above surface 31, such as, for example, the earth's surface or any other surface of interest. As such, platform 20 is capable of controlled movement or flight, either manned or unmanned, along a predefined flight path or course through, for example, the earth's atmosphere or outer space. Image-

capturing platform 20 includes a system for generating and regulating power (not shown) that includes, for example, one or more generators, fuel cells, solar panels, and/or batteries, for powering image-capturing system 30.

Image-capturing and geo-locating system 30, as best shown in Fig. 2, includes image capturing devices 32a and 32b, a global positioning system (GPS) receiver 34, an inertial navigation unit (INU) 36, clock 38, gyroscope 40, compass 42 and altimeter 44, each of which are interconnected with image-capturing computer system 46.

Image-capturing devices 32a and 32b, such as, for example, conventional cameras, digital cameras, digital sensors, charge-coupled devices, or other suitable image-capturing devices, are capable of capturing images photographically or electronically. Image-capturing devices 32a and 32b have known or determinable characteristics including focal length, sensor size and aspect ratio, radial and other distortion terms, principal point offset, pixel pitch, and alignment. Image-capturing devices 32a and 32b acquire images and issue image data signals (IDS) 48a and48b, respectively, corresponding to the particular images or photographs taken and which are stored in image-capturing computer system 46, as will be more particularly described hereinafter.

As best shown in Fig. 1, image-capturing devices 32a and 32b have respective central axes A_1 and A_2, and are mounted to platform 20 such that axes A_1 and A_2 are each at an angle of declination ? relative to a horizontal plane *P*. Declination angle ? is virtually any oblique angle, but is preferably from approximately 20° (twenty degrees) to

approximately 60° (sixty degrees) and is most preferably from approximately 40° (forty degrees) to approximately 50° (fifty degrees).

GPS receiver 34 receives global positioning system signals 52 that are transmitted by one or more global positioning system satellites 54. The GPS signals 52, in known fashion, enable the precise location of platform 20 relative to surface 31 to be determined. GPS receiver 34 decodes GPS signals 52 and issues location signals/data 56, that are dependent at least in part upon GPS signals 52 and which are indicative of the precise location of platform 20 relative to surface 31. Location signals/data 56 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

INU 36 is a conventional inertial navigation unit that is coupled to and detects changes in the velocity, including translational and rotational velocity, of image-capturing devices 32a and 32b and/or platform 20. INU 36 issues velocity signals/data 58 indicative of such velocities and/or changes therein to image-capturing computer system 46, which stores velocity signals/data 58 corresponding to each image captured by image-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Clock 38 keeps a precise time measurement (time of validity) that is used to synchronize events within image-capturing and geo-locating system 30. Clock 38 provides time data/clock signal 62 that is indicative of the precise time that an image is taken by image-capturing devices 32a and 32b. Time data 62 is also provided to and

stored by image-capturing computer system 46. Alternatively, clock 38 is integral with image-capturing computer system 46, such as, for example, a clock software program.

Gyroscope 40 is a conventional gyroscope as commonly found on airplanes and/or within commercial navigation systems for airplanes. Gyroscope 40 provides signals including pitch signal 64, roll signal 66 and yaw signal 68, which are respectively indicative of pitch, roll and yaw of platform 20. Pitch signal 64, roll signal 66 and yaw signal 68 corresponding to each image captured by mage-capturing devices 32a and 32b are received and stored by image-capturing computer system 46.

Compass 42, such as, for example, a conventional electronic compass, indicates the heading of platform 20. Compass 42 issues heading signal/data 72 that is indicative of the heading of platform 20. Image-capturing computer system 46 receives and stores the heading signals/data 72 that correspond to each image captured by image-capturing devices 32a and 32b.

Altimeter 44 indicates the altitude of platform 20. Altimeter 44 issues altitude signal/data 74, and image-capturing computer system 46 receives and stores the altitude signal/data 74 that correspond to each image captured by image-capturing devices 32a and 32b.

As best shown in Fig. 3, image-capturing computer system 46, such as, for example, a conventional laptop personal computer, includes memory 82, input devices 84a and 84b, display device 86, and input and output (I/O) ports 88. Image-capturing computer system 46 executes image and data acquiring software 90, which is stored in

memory 82. Memory 82 also stores data used and/or calculated by image-capturing computer system 46 during the operation thereof, and includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 84a and 84b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and interaction of a user with software being executed by image-capturing computer system 46. Display device 86, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image-capturing computer system 46. I/O ports 88, such as, for example, serial and parallel data input and output ports, enable the input and/or output of data to and from image-capturing computer system 46.

Each of the above-described data signals is connected to image-capturing computer system 46. More particularly, image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74 are received via I/O ports 88 by and stored within memory 82 of image-capturing computer system 46.

In use, image-capturing computer system 46 executes image and data acquiring software 90, which, in general, controls the reading, manipulation, and storing of the above-described data signals. More particularly, image and data acquiring software 90 reads image data signals 48a and 48b and stores them within memory 82. Each of the location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals

64, 66 and 68, respectively, heading signal 72 and altitude signal 74 that represent the conditions existing at the instant an image is acquired or captured by image-capturing devices 32a and 32b and which correspond to the particular image data signals 48a and 48b representing the captured images are received by image-capturing computer system 46 via I/O ports 88. Image-capturing computer system 46 executing image and data acquiring software 90 issues image-capture signal 92 to image-capturing devices 32a and 32b to thereby cause those devices to acquire or capture an image at predetermined locations and/or at predetermined intervals which are dependent at least in part upon the velocity of platform 20.

Image and data acquiring software 90 decodes as necessary and stores the aforementioned signals within memory 82, and associates the data signals with the corresponding image signals 48a and 48b. Thus, the altitude, orientation in terms of roll, pitch, and yaw, and the location of image-capturing devices 32a and 32b relative to surface 31, i.e., longitude and latitude, for every image captured by image-capturing devices 32a and 32b is known.

Platform 20 is piloted or otherwise guided through an image-capturing path that passes over a particular area of surface 31, such as, for example, a predefined area of the surface of the earth or of another planet. Preferably, the image-capturing path of platform 20 is at right angles to at least one of the boundaries of the area of interest. The number of times platform 20 and/or image-capturing devices 32a, 32b pass over the area of interest is dependent at least in part upon the size of the area and the

amount of detail desired in the captured images. The particular details of the image-capturing path of platform 20 are described more particularly hereinafter.

As platform 20 passes over the area of interest a number of oblique images are captured by image-capturing devices 32a and 32b. As will be understood by those of ordinary skill in the art, images are captured or acquired by image-capturing devices 32a and 32b at predetermined image capture intervals which are dependent at least in part upon the velocity of platform 20.

Image data signals 48a and 48b corresponding to each image acquired are received by and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Similarly, the data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) corresponding to each captured image are received and stored within memory 82 of image-capturing computer system 46 via I/O ports 88. Thus, the location of image-capturing device 32a and 32b relative to surface 32 at the precise moment each image is captured is recorded within memory 82 and associated with the corresponding captured image.

As best shown in Fig. 1, the location of image-capturing devices 32a and 32b relative to the earth corresponds to the nadir point *N* of orthogonal image 102. Thus, the exact geo-location of the nadir point *N* of orthogonal image 102 is indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74. Once the nadir

point *N* of orthogonal image 102 is known, the geo-location of any other pixel or point within image 102 is determinable in known manner.

When image-capturing devices 32a and 32b are capturing oblique images, such as oblique images 104a and 104b (Fig. 1), the location of image-capturing devices 32a and 32b relative to surface 31 is similarly indicated by location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72, altitude signal 74 and the known angle of declination ? of the primary axes A_1 *and* A_2 of image-capturing devices 32a and 32b, respectively.

It should be particularly noted that a calibration process enables image and data acquiring software 90 to incorporate correction factors and/or correct for any error inherent in or due to image-capturing device 32, such as, for example, error due to calibrated focal length, sensor size, radial distortion, principal point offset, and alignment.

Image and data acquiring software 90 creates and stores in memory 82 one or more output image and data files 120. More particularly, image and data acquiring software 90 converts image data signals 48a, 48b and the orientation data signals (i.e., image data signals 48, location signals 56, velocity signals 58, time data signal 62, pitch, roll and yaw signals 64, 66 and 68, respectively, heading signal 72 and altitude signal 74) into computer-readable output image and data files 120. As best shown in Fig. 4, output image and data file 120 contains a plurality of captured image files I_1, I_2, . . . , I_n corresponding to captured oblique images, and the positional data C_{PD1}, C_{PD2}, . . .

, C_{PDn} corresponding thereto.

Image files I_1, I_2, . . . , I_n of the image and data file 120 are stored in virtually any computer-readable image or graphics file format, such as, for example, JPEG, TIFF, GIF, BMP, or PDF file formats, and are cross-referenced with the positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} which is also stored as computer-readable data. Alternatively, positional data C_{PD1}, C_{PD2}, . . . , C_{PDn} is embedded within the corresponding image files I_1, I_2, . . . , I_n in known manner. Image data files 120 are then processed, either by image and data acquiring software 90 or by post-processing, to correct for errors, such as, for example, errors due to flight path deviations and other errors known to one of ordinary skill in the art. Thereafter, image data files 120 are ready for use to display and make measurements of and between the objects depicted within the captured images, including measurements of the heights of such objects.

Referring now to Fig. 5, image display and measurement computer system 130, such as, for example, a conventional desktop personal computer or a mobile computer terminal in a police car, includes memory 132, input devices 134a and 134b, display device 136, and network connection 138. Image-capturing computer system 130 executes image display and analysis software 140, which is stored in memory 132. Memory 132 includes, for example, non-volatile read-only memory, random access memory, hard disk memory, removable memory cards and/or other suitable memory storage devices and/or media. Input devices 134a and 134b, such as, for example, a mouse, keyboard, joystick, or other such input devices, enable the input of data and

interaction of a user with image display and analysis software 140 being executed by image display and measurement computer system 130. Display device 136, such as, for example, a liquid crystal display or cathode ray tube, displays information to the user of image display and measurement computer system 130. Network connection 138 connects image display and measurement computer system 130 to a network (not shown), such as, for example, a local-area network, wide-area network, the Internet and/or the World Wide Web.

In use, and referring now to Fig. 6, image display and measurement computer system 130 executing image display and analysis software 140 accesses one or more output image and data files 120 that have been read into memory 132, such as, for example, via network connection 138, a floppy disk drive, removable memory card or other suitable means. One or more of the captured images I_1, I_2, . . . , I_n of output image and data files 120 is thereafter displayed as displayed oblique image 142 under the control of image display and analysis software 140. At approximately the same time, one or more data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} corresponding to displayed oblique image 142 are read into a readily-accessible portion of memory 132.

It should be particularly noted that displayed oblique image 142 is displayed substantially as captured, i.e., displayed image 142 is not warped or fitted to any coordinate system nor is displayed image 142 ortho-rectified. Rather than warping displayed image 142 to a coordinate system in order to enable measurement of objects depicted therein, image display and analysis software 140, in general, determines the

geo-locations of selected pixels only as needed, or "on the fly", by referencing data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 and calculating the position and/or geo-location of those selected pixels using one or more projection equations as is more particularly described hereinafter.

Generally, a user of display and measurement computer system 130 takes measurements of and between objects depicted in displayed oblique image 142 by selecting one of several available measuring modes provided within image display and analysis software 140. The user selects the desired measurement mode by accessing, for example, a series of pull-down menus or toolbars *M*, or via keyboard commands. The measuring modes provided by image display and analysis software 140 include, for example, a distance mode that enables measurement of the distance between two or more selected points, an area mode that enables measurement of the area encompassed by several selected and interconnected points, a height mode that enables measurement of the height between two or more selected points, and an elevation mode that enables the measurement of the change in elevation of one selected point relative to one or more other selected points.

After selecting the desired measurement mode, the user of image display and analysis software 140 selects with one of input devices 134a, 134b a starting point or starting pixel 152 and an ending point or pixel 154 on displayed image 142, and image display and analysis software 140 automatically calculates and displays the quantity sought, such as, for example, the distance between starting pixel 152 and ending pixel

154.

When the user selects starting point/pixel 152, the geo-location of the point corresponding thereto on surface 31 is calculated by image display and analysis software 140 which executes one or more projection equations using the data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data files 120 that correspond to the particular image being displayed. The longitude and latitude of the point on surface 31 corresponding to pixel 152 are then displayed by image display and analysis software 140 on display 136, such as, for example, by superimposing the longitude and latitude on displayed image 142 adjacent the selected point/pixel or in pop-up display box elsewhere on display 136. The same process is repeated by the user for the selection of the end pixel/point 154, and by image display and analysis software 140 for the retrieval and display of the longitude and latitude information.

The calculation of the distance between starting and ending points/pixels 152, 154, respectively, is accomplished by determining the geo-location of each selected pixel 152, 154 "on the fly". The data portions C_{PD1}, C_{PD2}, . . . , C_{PDn} of output image and data file 120 corresponding to the displayed image are retrieved, and the geo-location of the point on surface 31 corresponding to each selected pixel are then determined. The difference between the geo-locations corresponding to the selected pixels determines the distance between the pixels.

As an example of how the geo-location of a given point or pixel within displayed oblique image 142 is determined, we will assume that displayed image 142

corresponds to orthogonal image 104a (Fig. 1). The user of image display and analysis software 140 selects pixel 154 which, for simplicity, corresponds to center *C* (Fig. 1) of oblique image 104a. As shown in Fig. 1, line 106 extends along horizontal plane *G* from a point 108 thereon that is directly below image-capturing device 32a to the center *C* of the near border or edge 108 of oblique image 104a. An extension of primary axis A_1 intersects with center *C*. Angle Ø is the angle formed between line 106 the extension of primary axis A_1. Thus, a triangle (not referenced) is formed having vertices at image-capturing device 32a, point 108 and center *C*, and having sides 106, the extension of primary axis A_1 and vertical (dashed) line 110 between point 108 and image-capturing device 32a.

Ground plane *G* is a substantially horizontal, flat or non-sloping ground plane (and which typically will have an elevation that reflects the average elevation of the terrain), and therefore the above-described triangle includes a right angle between side/line 110 and side/line 106. Since angle Ø and the altitude of image-capturing device 32 (i.e., the length of side 110) are known, the hypotenuse (i.e., the length of the extension of primary axis A_1) and remaining other side of the right triangle are calculated by simple geometry. Further, since the exact position of image-capturing device 32a is known at the time the image corresponding to displayed image 142 was captured, the latitude and longitude of point 108 are also known. Knowing the length of side 106, calculated as described above, enables the exact geo-location of pixel 154 corresponding to center *C* of oblique image 104a to be determined by image display

and analysis software 140. Once the geo-location of the point corresponding to pixel 154 is known, the geo-location of any other pixel in displayed oblique image 142 is determinable using the known camera characteristics, such as, for example, focal length, sensor size and aspect ratio, radial and other distortion terms, etc.

The distance between the two or more points corresponding to two or more selected pixels within displayed image 142 is calculated by image display and analysis software 140 by determining the difference between the geo-locations of the selected pixels using known algorithms, such as, for example, the Gauss formula and/or the vanishing point formula, dependent upon the selected measuring mode. The measurement of objects depicted or appearing in displayed image 142 is conducted by a substantially similar procedure to the procedure described above for measuring distances between selected pixels. For example, the lengths, widths and heights of objects, such as, for example, buildings, rivers, roads, and virtually any other geographic or man-made structure, appearing within displayed image 142 are measured by selecting the appropriate/desired measurement mode and selecting starting and ending pixels.

It should be particularly noted that in the distance measuring mode of image display and analysis software 140 the distance between the starting and ending points/pixels 152, 154, respectively, is determinable along virtually any path, such as, for example, a "straight-line" path *P1* or a path *P2* that involves the selection of intermediate points/pixels and one or more "straight-line" segments interconnected

therewith.

It should also be particularly noted that the distance measuring mode of image display and analysis software 140 determines the distance between selected pixels according to a "walk the earth" method. The "walk the earth method" creates a series of interconnected line segments, represented collectively by paths *P1* and *P2*, that extend between the selected pixels/points and which lie upon or conform to the planar faces of a series of interconnected facets that define a tessellated ground plane. The tessellated ground plane, as will be more particularly described hereinafter, closely follows or recreates the terrain of surface 31, and therefore paths *P1* and *P2* also closely follow the terrain of surface 31. By measuring the distance along the terrain simulated by the tessellated ground plane, the "walk the earth" method provides for a more accurate and useful measurement of the distance between selected points than the conventional approach, which warps the image onto a flat earth or average elevation plane system and measures the distance between selected points along the flat earth or plane and substantially ignores variations in terrain between the points.

For example, a contractor preparing to bid on a contract for paving a roadway over uneven or hilly terrain can determine the approximate amount or area of roadway involved using image display and analysis software 140 and the "walk the earth" measurement method provided thereby. The contractor can obtain the approximate amount or area of roadway from his or her own office without having to send a surveying crew to the site to obtain the measurements necessary.

In contrast to the "walk the earth" method provided by the present invention, the "flat earth" or average elevation distance calculating approaches include inherent inaccuracies when measuring distances between points and/or objects disposed on uneven terrain and when measuring the sizes and/or heights of objects similarly disposed. Even a modest slope or grade in the surface being captured results in a difference in the elevation of the nadir point relative to virtually any other point of interest thereon. Thus, referring again to Fig. 1, the triangle formed by line 106, the extension of primary axis A_1 and the vertical (dashed) line 110 between point 108 and image-capturing device 32a may not be a right triangle. If such is the case, any geometric calculations assuming that triangle to be a right triangle would contain errors, and such calculations would be reduced to approximations due to even a relatively slight gradient or slope between the points of interest.

For example, if surface 31 slopes upward between nadir point *N* and center *C* at the near or bottom edge 108 of oblique image 104 then second line 110 intersects surface 31 before the point at which such intersection would occur on a level or non-sloping surface 31. If center *C* is fifteen feet higher than nadir point *N* and with a declination angle ? equal to 40° (forty degrees), the calculated location of center *C* would be off by approximately 17.8 feet without correction for the change in elevation between the points.

As generally discussed above, in order to compensate at least in part for changes in elevation and the resultant inaccuracies in the measurement of and

between objects within image 142, image display and analysis software 140 references, as necessary, points within displayed image 142 and on surface 31 to a pre-calculated tessellated or faceted ground plane generally designated 160 in Fig. 6. Tessellated ground plane 160 includes a plurality of individual facets 162a, 162b, 162c, etc., each of which are interconnected to each other and are defined by four vertices (not referenced, but shown as points) having respective elevations. Adjacent pairs of facets 162a, 162b, 162c, etc., share two vertices. Each facet 162a, 162b, 162c, etc., has a respective pitch and slope. Tessellated ground plane 160 is created based upon various data and resources, such as, for example, topographical maps, and/or digital raster graphics, survey data, and various other sources.

Generally, the geo-location of a point of interest on displayed image 142 is calculated by determining which of facets 162a, 162b, 162c, etc., correspond to that point of interest. Thus, the location of the point of interest is calculated based on the characteristics, i.e., elevation, pitch and slope, of facets 162a, 162b, 162c, etc., rather than based upon a flat or average-elevation ground plane. Error is introduced only in so far as the topography of surface 31 and the location of the point of interest thereon deviate from the planar surface of the facet 162a, 162b, 162c, etc, within which the point of interest lies. That error is reducible through a bilinear interpolation of the elevation of the point of interest within a particular one of facets 162a, 162b, 162c, etc., and using that interpolated elevation in the location calculation performed by image display and analysis software 140.

To use tessellated ground plane 160, image display and analysis software 140 employs a modified ray-tracing algorithm to find the intersection of the ray projected from the image-capturing device 32a or 32b towards surface 31 and tessellated ground plane 160. The algorithm determines not only which of facets 162a, 162b, 162c, etc., is intersected by the ray, but also where within the facet the intersection occurs. By use of bi-linear interpolation, a fairly precise ground location can be determined. For the reverse projection, tessellated ground plane 160 is used to find the ground elevation value for the input ground location also using bi-linear interpolation. The elevation and location are then used to project backwards through a model of the image-capturing device 32a or 32b to determine which of the pixels within displayed image 142 corresponds to the given location.

More particularly, and as an example, image display and analysis software 140 performs and/or calculates the geo-location of point 164 by superimposing and/or fitting tessellated ground plane 160 to at least a portion 166, such as, for example, a hill, of surface 31. It should be noted that only a small portion of tessellated ground plane 160 and facets 162a, 162b, 162c, etc., thereof is shown along the profile of portion 166 of surface 31. As discussed above, each of facets 162a, 162b, 162c, etc., are defined by four vertices, each of which have respective elevations, and each of the facets have respective pitches and slopes. The specific position of point 164 upon the plane/surface of the facet 162a, 162b, 162c, etc., within which point 164 (or its projection) lies is determined as described above.

Tessellated ground plane 160 is preferably created outside the operation of image display and measurement computer system 130 and image display and analysis software 140. Rather, tessellated ground plane 160 takes the form of a relatively simple data table or look-up table 168 stored within memory 132 of and/or accessible to image display and measurement computer system 130. The computing resources required to calculate the locations of all the vertices of the many facets of a typical ground plane do not necessarily have to reside within image display and measurement computer system 130. Thus, image display and measurement computer system 130 is compatible for use with and executable by a conventional personal computer without requiring additional computing resources.

Calculating tessellated ground plane 160 outside of image display and measurement computer system 130 enables virtually any level of detail to be incorporated into tessellated ground plane 160, i.e., the size and/or area covered by or corresponding to each of facets 162a, 162b, 162c, etc., can be as large or as small as desired, without significantly increasing the calculation time, slowing the operation of, nor significantly increasing the resources required by image display and measurement computer system 130 and/or image display and analysis software 140. Display and measurement computer system 130 can therefore be a relatively basic and uncomplicated computer system.

The size of facets 162a, 162b, 162c, etc., are uniform in size throughout a particular displayed image 142. For example, if displayed image 142 corresponds to an

area that is approximately 750 feet wide in the foreground by approximately 900 feet deep, the image can be broken into facets that are approximately 50 square feet, thus yielding about 15 facets in width and 18 facets in depth. Alternatively, the size of facets 162a, 162b, 162c, etc., are uniform in terms of the number of pixels contained therein, i.e., each facet is the same number of pixels wide and the same number of pixels deep. Facets in the foreground of displayed image 142, where the pixel density is greatest, would therefore be dimensionally smaller than facets in the background of displayed image 142 where pixel density is lowest. Since it is desirable to take most measurements in the foreground of a displayed image where pixel density is greatest, creating facets that are uniform in terms of the number of pixels they contain has the advantage of providing more accurate measurements in the foreground of displayed image 142 relative to facets that are dimensionally uniform.

Another advantage of using pixels as a basis for defining the dimensions of facets 162a, 162b, 162c, etc., is that the location calculation (pixel location to ground location) is relatively simple. A user operates image display and measurement computer system 130 to select a pixel within a given facet, image display and analysis software 140 looks up the data for the facet corresponding to the selected pixel, the elevation of the selected pixel is calculated as discussed above, and that elevation is used within the location calculation.

Generally, the method of capturing oblique images of the present invention divides an area of interest, such as, for example, a county, into sectors of generally

uniform size, such as, for example, sectors that are approximately one square mile in area. This is done to facilitate the creation of a flight plan to capture oblique images covering every inch of the area of interest, and to organize and name the sectors and/or images thereof for easy reference, storage and retrieval (a process known in the art as "sectorization"). Because the edges of any geographic area of interest, such as a county, rarely falls on even square mile boundaries, the method of capturing oblique images of the present invention provides more sectors than there are square miles in the area of interest – how many more depends largely on the length of the county borders as well as how straight or jagged they are. Typically, you can expect one extra sector for every two to three miles of border. So if a county or other area of interest is roughly 20 miles by 35 miles, or 700 square miles, the area will be divided into approximately from 740 to 780 sectors.

The method of capturing oblique images of the present invention, in general, captures the oblique images from at least two compass directions, and provides full coverage of the area of interest from at least those two compass directions. Referring now to Figs. 7 and 8, a first embodiment of a method for capturing oblique images of the present invention is shown. For sake of clarity, Fig. 7 and 8 is based on a system having only one image-capturing device. However, it is to be understood that two or more image-capturing devices can be used.

The image-capturing device captures one or more oblique images during each pass over area 200. The image-capturing device, as discussed above, is aimed at an

angle over area 200 to capture oblique images thereof. Area 200 is traversed in a back-and-forth pattern, similar to the way a lawn is mowed, by the image-carrying device and/or the platform to ensure double coverage of area 200.

More particularly, area 200 is traversed by image-carrying device 32 and/or platform 20 following a first path 202 to thereby capture oblique images of portions 202a, 202b, and 202c of area 200. Area 200 is then traversed by image-carrying device 32 and/or platform 20 following a second path 204 that is parallel and spaced apart from, and in an opposite direction to, i.e., 180° (one-hundred and eighty degrees) from, first path 202, to thereby capture oblique images of portions 204a, 204b, 204c of area 200. By comparing Figs. 7 and 8, it is seen that a portion 207 (Fig. 8) of area 200 is covered by images 202a-c captured from a first direction or perspective, and by images 204a-c captured from a second direction or perspective. As such, the middle portion of area 200 is 100% (one-hundred percent) double covered. The above-described pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 202 and 204 is repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from each other as dictated by the size of area 200, and in the same direction as paths 202 and 204 to thereby one-hundred percent double cover area 200 from those perspectives/directions.

If desired, and for enhanced detail, area 200 is covered by two additional opposing and parallel third and fourth paths 206 and 208, respectively, that are

perpendicular to paths 202 and 204 as shown in Figs. 9 and 10. Area 200 is therefore traversed by image-carrying device 32 and/or platform 20 following third path 206 to capture oblique images of portions 206a, 206b and 206c of area 200, and is then traversed along fourth path 208 that is parallel, spaced apart from, and opposite to third path 206 to capture oblique images of portions 208a, 208b and 208c of area 200. This pattern of traversing or passing over area 200 along opposing paths that are parallel to paths 206 and 208 is similarly repeated until the entirety of area 200 is completely covered by at least one oblique image captured from paths that are parallel to, spaced apart from as dictated by the size of area 200, and in the same direction as paths 206 and 208 to thereby one-hundred percent double cover area 200 from those directions/perspectives.

As described above, image-carrying device 32 and/or platform 20, traverses or passes over area 200 along a predetermined path. However, it is to be understood that image-carrying device and/or platform 20 do not necessarily pass or traverse directly over area 200 but rather may pass or traverse an area adjacent, proximate to, or even somewhat removed from, area 200 in order to ensure that the portion of area 200 that is being imaged falls within the image-capture field of the image-capturing device. Path 202, as shown in Fig. 7, is such a path that does not pass directly over area 200 but yet captures oblique images thereof.

The present invention is capable of capturing images at various levels of resolution or ground sample distances. A first level of detail, hereinafter referred to as a

community level, has a ground sample distance of, for example, approximately two-feet per pixel. For orthogonal community-level images, the ground sample distance remains substantially constant throughout the image. Orthogonal community-level images are captured with sufficient overlap to provide stereo pair coverage. For oblique community-level images, the ground sample distance varies from, for example, approximately one-foot per pixel in the foreground of the image to approximately two-feet per pixel in the mid-ground of the image, and to approximately four-feet per pixel in the background of the image. Oblique community-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction captured. Approximately ten oblique community-level images are captured per sector.

A second level of detail, hereinafter referred to as a neighborhood level, is significantly more detailed than the community-level images. Neighborhood-level images have a ground sample distance of, for example, approximately six-inches per pixel. For orthogonal neighborhood-level images, the ground sample distance remains substantially constant. Oblique neighborhood-level images have a ground sample distance of, for example, from approximately four-inches per pixel in the foreground of the image to approximately six-inches per pixel in the mid-ground of the image, and to approximately ten-inches per pixel in the background of the image. Oblique neighborhood-level images are captured with sufficient overlap such that each area of interest is typically covered by at least two oblique images from each compass direction

captured, and such that opposing compass directions provide 100% overlap with each other. Approximately one hundred (100) oblique area images are captured per sector.

It should be particularly noted that capturing oblique community and/or neighborhood-level images from all four compass directions ensures that every point in the image will appear in the foreground or lower portion of at least one of the captured oblique images, where ground sample distance is lowest and image detail is greatest.

In the embodiment shown, image-capturing and geo-locating system 30 includes a gyroscope, compass and altimeter. However, it is to be understood that the image-capturing and geo-locating system of the present invention can be alternately configured, such as, for example, to derive and/or calculate altitude, pitch, roll and yaw, and compass heading from the GPS and INU signals/data, thereby rendering one or more of the gyroscope, compass and altimeter unnecessary. In fact,

In the embodiment shown, image-capturing devices are at an equal angle of declination relative to a horizontal plane. However, it is to be understood that the declination angles of the image-capturing devices do not have to be equal.

In the embodiment shown, image-capturing computer system executes image and data acquiring software that issues a common or single image-capture signal to the image-capturing devices to thereby cause those devices to acquire or capture an image. However, it is to be understood that the present invention can be alternately configured to separately cause the image-capturing devices to capture images at different instants and/or at different intervals.

In the embodiment shown, the method of the present invention captures oblique images to provide double coverage of an area of interest from paths/perspectives that are substantially opposite to each other, i.e., 180° (one-hundred and eighty degrees) relative to each other. However, it is to be understood that the method of the present invention can be alternately configured to provide double coverage from paths/perspectives that are generally and/or substantially perpendicular relative to each other.

While the present invention has been described as having a preferred design, the invention can be further modified within the spirit and scope of this disclosure. This disclosure is therefore intended to encompass any equivalents to the structures and elements disclosed herein. Further, this disclosure is intended to encompass any variations, uses, or adaptations of the present invention that use the general principles disclosed herein. Moreover, this disclosure is intended to encompass any departures from the subject matter disclosed that come within the known or customary practice in the pertinent art and which fall within the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A system for capturing images and geo-location data corresponding thereto, comprising:

an image-capturing device, said image-capturing device capturing oblique images at image-capturing events, said image capturing device issuing image-data signals corresponding to captured images;

at least one geo-locating device, each said at least one geo-locating device issuing a corresponding at least one geo-locating signal, each said at least one geo-locating signal being indicative at least in part of a geo-location of said image-capturing device during each image capturing event; and

a computer system receiving and storing said image-data signals and said at least one geo-locating signal; and

image and data acquiring software reading said image-data signals and said at least one geo-locating signal, said software associating each said image-data signal with a corresponding said at least one geo-locating signal for each image-capturing event.

2. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise at least one of:

a clock issuing to said image-capturing computer system time data signals

indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

3. The system of claim 1, wherein said at least one geo-locating device and said at least one geo-locating signal respectively comprise:

a clock issuing to said image-capturing computer system time data signals indicative of a time of each said image-capturing event;

a global-positioning system (GPS) receiver receiving GPS signals and issuing to said image-capturing computer system location data signals indicative of a longitude and latitude of said image-capturing device at each said image-capturing event;

an inertial navigation unit (INU) issuing to said image-capturing computer system velocity data signals indicative of a velocity of said image-capturing device at each said image-capturing event;

a gyroscope issuing to said image-capturing computer system a pitch signal, a roll signal, and a yaw signal respectively indicative of a pitch, roll and yaw of said image capturing device at each said image-capturing event;

a compass issuing to said image-capturing computer system heading data signals indicative of a heading of said image-capturing device at each said image-capturing event; and

an altimeter issuing to said image-capturing computer system altitude data signals indicative of an altitude of said image-capturing device at each said image-capturing event.

4. The system of claim 1, further comprising correction data indicative of characteristics of said image-capturing device including focal length, sensor size, radial distortion, principal point offset and alignment, said image and data acquiring software utilizing said correction data to correct captured images.

5. The system of claim 1, further comprising an output data file created by said image and data acquiring software, said output data file including a plurality of image files and positional data corresponding to each of said plurality of image files.

6. The system of claim 1, further comprising a platform carrying said image-capturing device a predetermined distance above a surface of interest.

7. A computerized system for displaying, geolocating, and making measurements based upon captured oblique images, comprising:

a computer system having a memory;

an image and data file accessible by said system and including a plurality of image files corresponding to a plurality of captured oblique images, said image and data file further including positional data corresponding to said plurality of image files;

image display and analysis software executed by said system for reading said image and data file and displaying at least a portion of the captured oblique images as a displayed image, said software retrieving said positional data of one or more selected points within said displayed image, said software calculating a separation distance between any two or more selected points within said displayed image.

8. The system of claim 7, further comprising a ground plane data file representing a tessellated ground plane, said ground plane data file accessible by said

computer system, said ground plane data file representing a tessellated ground plane that closely approximates at least a portion of the terrain depicted within said captured oblique images.

9. The system of claim 8, wherein said tessellated ground plane further comprises a plurality of interconnected facets, each of said plurality of facets having a respective pitch and slope.

10. The system of claim 9, wherein said ground plane data file comprises a plurality of vertices, each of said plurality of vertices having respective elevations and defining corners of said plurality of interconnected facets, two of said plurality of vertices shared by each of said interconnected facets.

11. The system of claim 10, wherein said image display and analysis software identifies which of said plurality of facets corresponds to a selected point on said displayed image, and calculates an elevation of said selected point dependent at least in part upon the elevation of the vertices of the facet corresponding to the selected point, said image display and analysis software using said calculated elevation for calculating said separation distance between said selected point and one or more further selected points.

12. The system of claim 11, wherein said image display and analysis software calculates a height of an object within said displayed image by calculating the separation distance between two or more selected points.

13. The system of claim 8, wherein said tessellated ground plane is one of superimposed upon and fit to said displayed image.

14. The system of claim 7, wherein said image display and analysis software includes user-selectable measuring modes accessible through at least one of pull-down menus, toolbars and keyboard commands.

15. The system of claim 7, wherein each of said images were captured by an image-capturing device and at respective image capturing events, said positional data of said image and data file including:

time data representing the time of each image-capturing event;

location data representing the location of the image-capturing device at each image-capturing event;

orientation data representing the orientation of the image-capturing device at each image-capturing event;

correction data representing correction factors for the image-capturing device; and

elevation data representing an average elevation of the surface captured by the image-capturing device.

16. The system of claim 15, wherein said location data includes latitude, longitude, and altitude of the image-capturing apparatus at each image-capturing event.

17. The system of claim 15, wherein said orientation data includes roll, pitch, yaw and heading of said image-capturing device at each image-capturing event.

18. The data set of claim 15, wherein said image-capturing device is a camera and said correction data includes at least one of focal length, sensor size, aspect ratio, principle point offset, distortion, and pixel pitch.

19. A computerized method for taking measurements within a displayed oblique image, comprising:

selecting with an input device a starting point and an end point on the displayed image;

retrieving from a data file positional data corresponding to said starting point and said end point;

referencing a ground plane data file corresponding to a tessellated ground plane having a plurality of facets, each of said facets having a respective pitch and slope, said

tessellated ground plane closely matching a terrain of said displayed oblique image;

connecting said starting and end points with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the linear distance along said line segments between said starting and end points thereby taking into account said pitch and slope of said facets.

20. The method of claim 19, wherein said tessellated ground plane is superimposed upon said displayed oblique image.

21. The method of claim 19, comprising the further steps of:

selecting with an input device one or more intermediate points on the displayed image;

retrieving from said data file positional data corresponding to said one or more intermediate points; and

connecting adjacent intermediate points to each other, and connecting said starting and end points to adjacent intermediate points, with line segments, said line segments conforming to said pitch and slope of said facets to thereby follow said terrain; and

calculating the distance along said line segments between said starting and end points.

22. The method of claim 19, wherein said plurality of facets each correspond to equal areas of said displayed oblique image.

23. The method of claim 19, wherein said plurality of facets each includes an equal number of pixels of said displayed oblique image.

24. A computerized method for taking measurements from an oblique image displayed on a computer system, at least one input device connected to said computer system, an image data file accessible by said computer system, said image data file including captured images and positional data corresponding thereto, said computerized method comprising:

placing the computer system into a desired one of a plurality of measurement modes, the desired measurement mode configured for calculating a desired measurement;

selecting a starting point on the displayed image;

retrieving the positional data corresponding to said starting point;

selecting an end point on the displayed image;

retrieving the positional data corresponding to said end point; and

calculating the desired measurement dependent at least in part upon said positional data of said starting and end points.

25. The method of claim 24, comprising the further steps of:

selecting one or more intermediate points on said displayed image; and

retrieving the positional data corresponding to said intermediate points.

26. The method of claim 24, wherein said plurality of measurement modes comprise a distance measuring mode calculating a distance between two or more selected points, a height measuring mode calculating a height difference between two or more selected points, a relative elevation measurement mode calculating the difference in elevation of two or more selected points, and an area measurement mode calculating the area encompassed by at least three points.

27. A method of capturing oblique images of an area of interest with an image-capturing device carried by a platform, each oblique image captured at a respective image-capturing event, said method comprising:

subdividing the area of interest into a plurality of sectors;

guiding the platform along a first path to thereby target one or more target sectors with the image-capturing device;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a first perspective;

guiding the platform along a second path to thereby target said target sectors;

capturing with the image-capturing device one or more oblique images to thereby cover an entirety of each said target sector in oblique images captured from a second perspective;

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said first and second paths and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from each of said first and second perspectives; and

recording positional data indicative of a geo-location of said image-capturing device at each image-capturing event.

28. The method of claim 27, wherein said second path is substantially parallel relative to and 180° (one-hundred and eighty degrees) from said first path;

29. The method of claim 28, wherein said second path is also spaced apart from said first path.

30. The method of claim 27, comprising the further steps of:

guiding the platform along a third path to thereby target one or more target sectors with the image-capturing device, said third path being substantially perpendicular to said first and second paths;

capturing with the image-capturing device one or more oblique images to thereby

capture an entirety of each said target sector in oblique images captured from a third perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said third path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said third perspective.

31. The method of claim 30, comprising the further steps of:

guiding the platform along a fourth path to thereby target one or more target sectors with the image-capturing device, said fourth path being substantially parallel with said third path and 180° (one-hundred and eighty degrees) from said third path;

capturing with the image-capturing device one or more oblique images to thereby capture an entirety of each said target sector in oblique images captured from a fourth perspective; and

repeating said guiding and capturing steps along paths substantially parallel to and spaced apart from said fourth path and capturing one or more oblique images to thereby cover an entirety of each of said plurality of sectors in oblique images captured from said fourth perspective.

32. The method of claim 31, wherein said fourth path is also spaced apart from said third path.

WO 2004/044692 PCT/US2003/035528

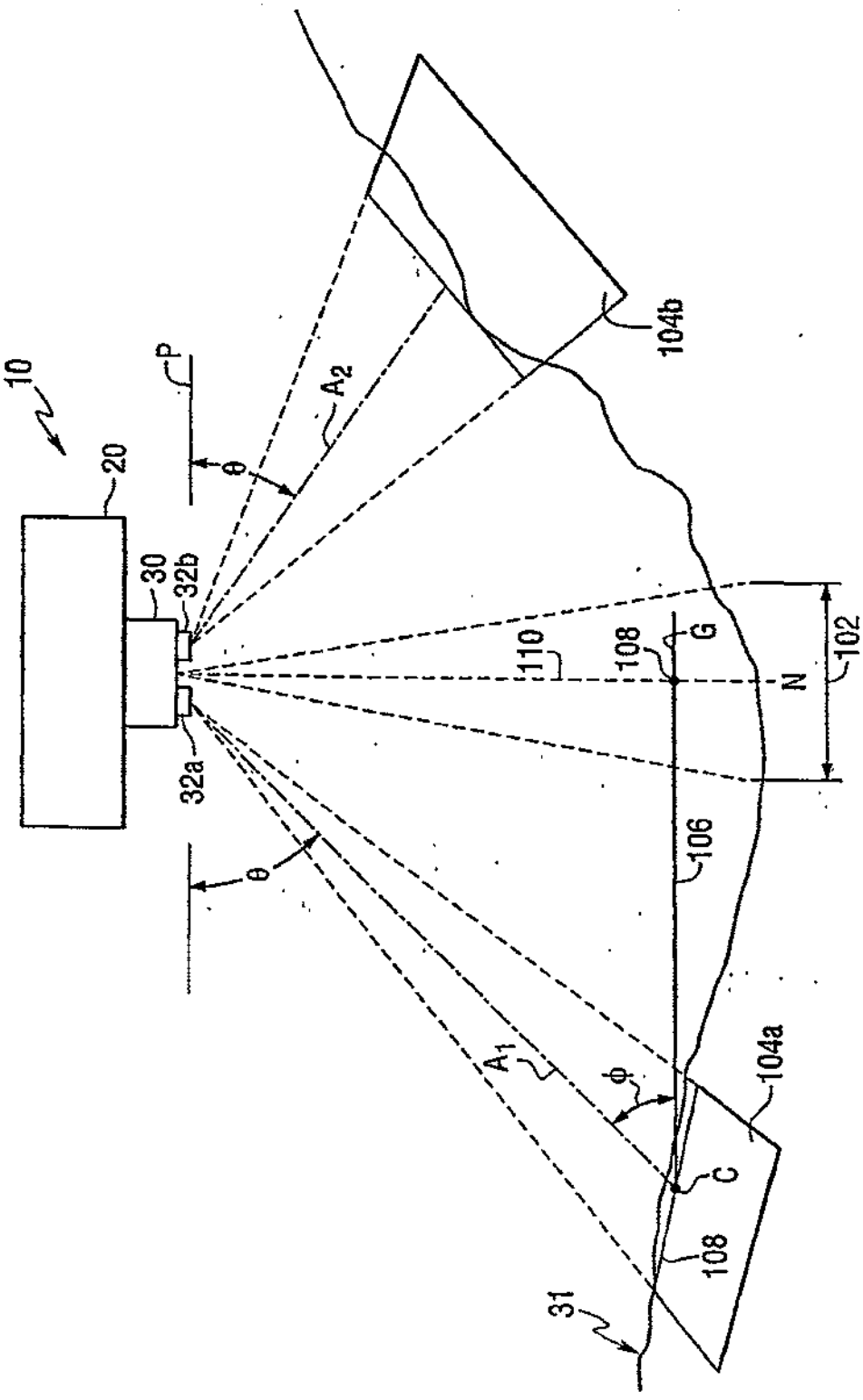


FIG. 1

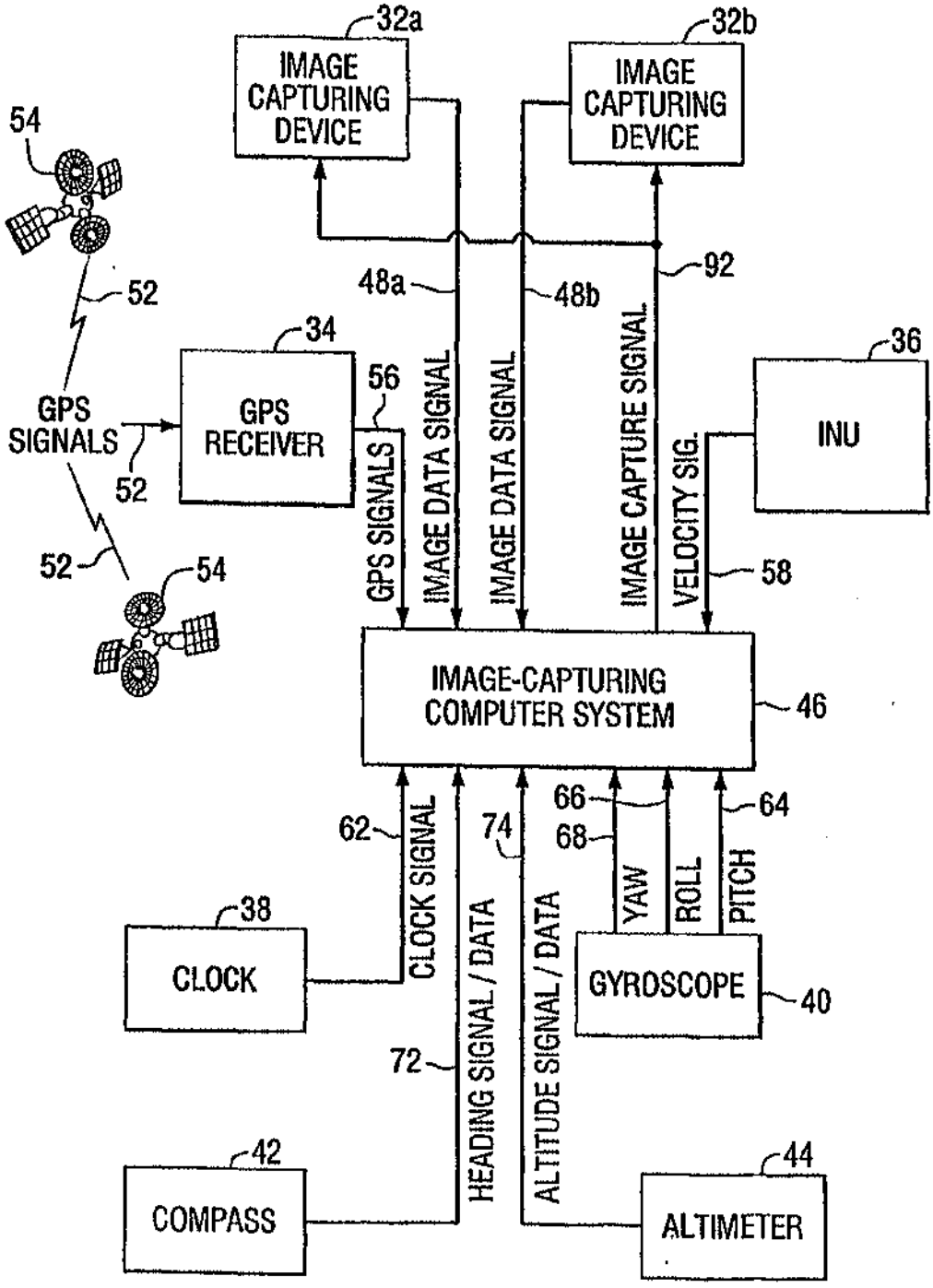

32a
IMAGE CAPTURING DEVICE
32b
IMAGE CAPTURING DEVICE
54
52
48a
48b
92
34
GPS SIGNALS
GPS RECEIVER
56
36
INU
52
52
54
GPS SIGNALS
IMAGE DATA SIGNAL
IMAGE DATA SIGNAL
IMAGE CAPTURE SIGNAL
VELOCITY SIG.
58
IMAGE-CAPTURING COMPUTER SYSTEM
46
62
CLOCK SIGNAL
74
66
68
64
YAW
ROLL
PITCH
38
CLOCK
HEADING SIGNAL / DATA
ALTITUDE SIGNAL / DATA
GYROSCOPE
40
72
42
COMPASS
44
ALTIMETER

FIG. 2

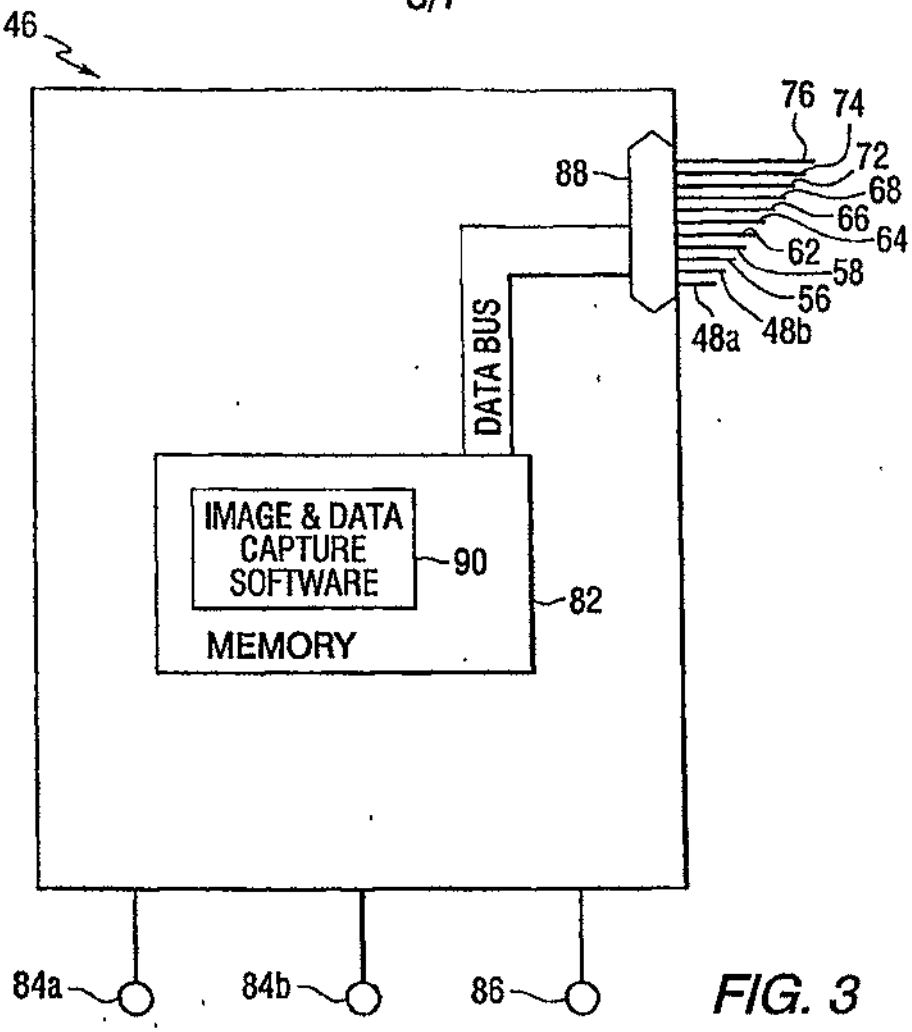

46
76
74
72
68
66
64
62
58
56
48a
48b
88
DATA BUS
IMAGE & DATA CAPTURE SOFTWARE
90
82
MEMORY
84a
84b
86

FIG. 3

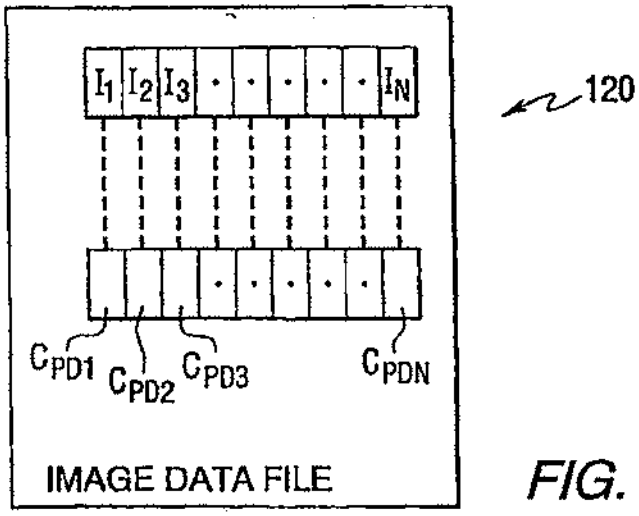

I_1 I_2 I_3 I_N
120
C_{PD1} C_{PD2} C_{PD3} C_{PDN}
IMAGE DATA FILE

FIG. 4

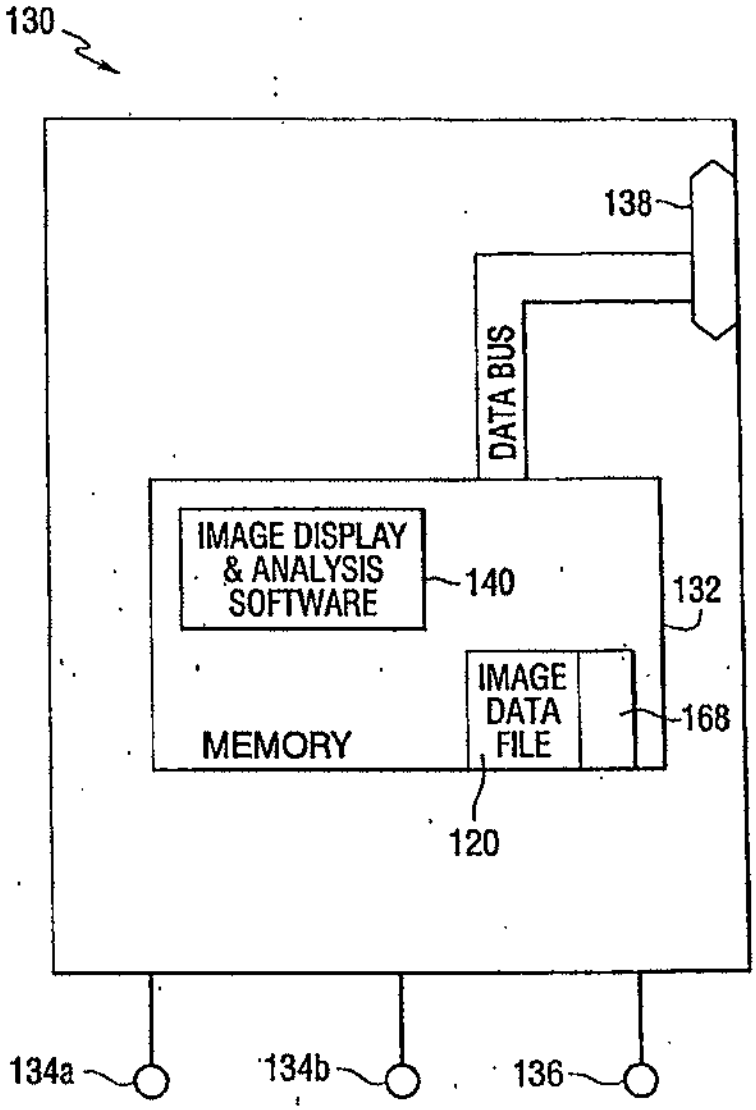

130
138
DATA BUS
IMAGE DISPLAY & ANALYSIS SOFTWARE
140
132
IMAGE DATA FILE
168
MEMORY
120
134a
134b
136

FIG. 5

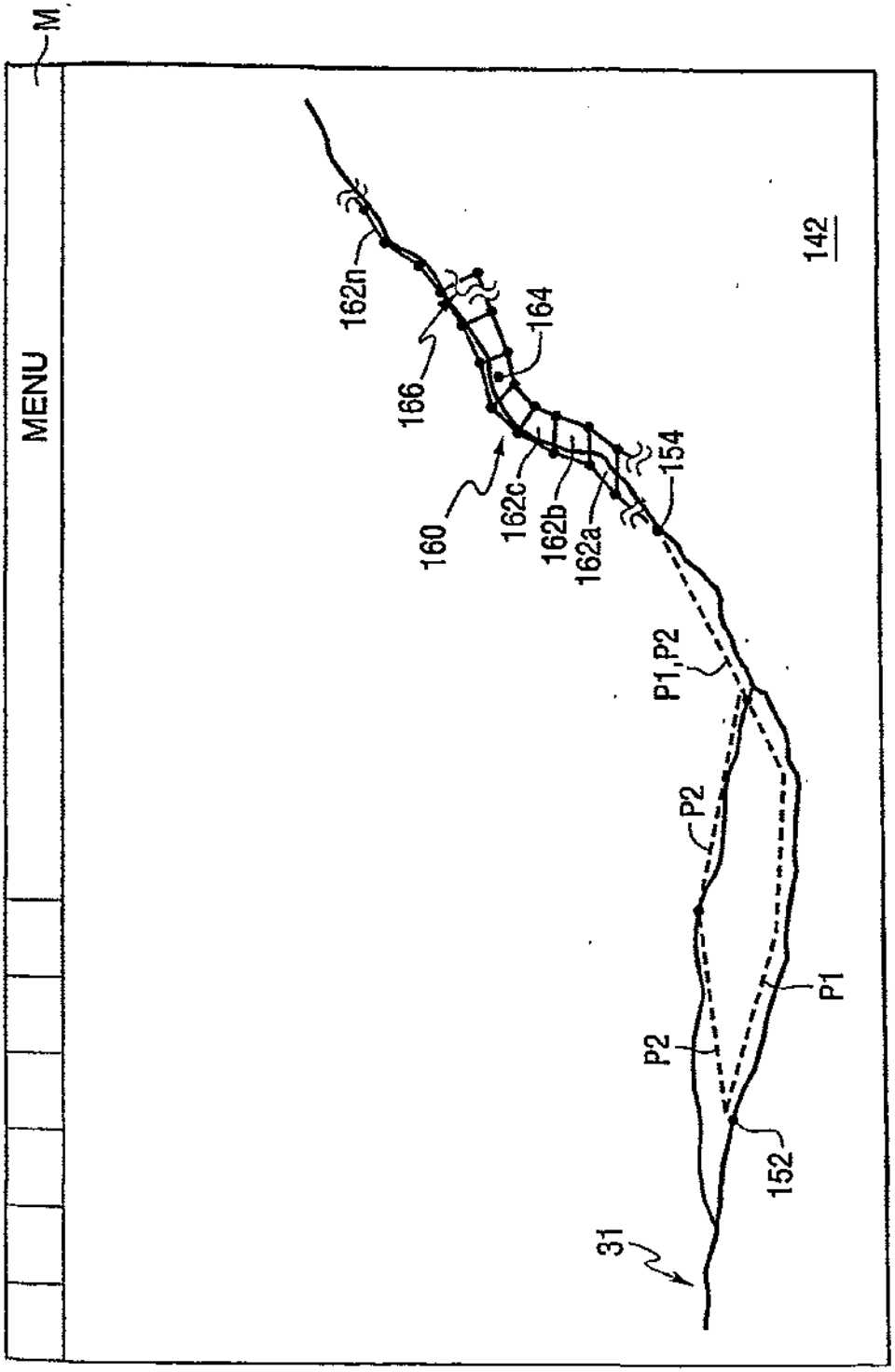

M
MENU
142
162n
166
164
160
162c
162b
162a
154
P1,P2
P2
P1
P2
152
31

FIG. 6

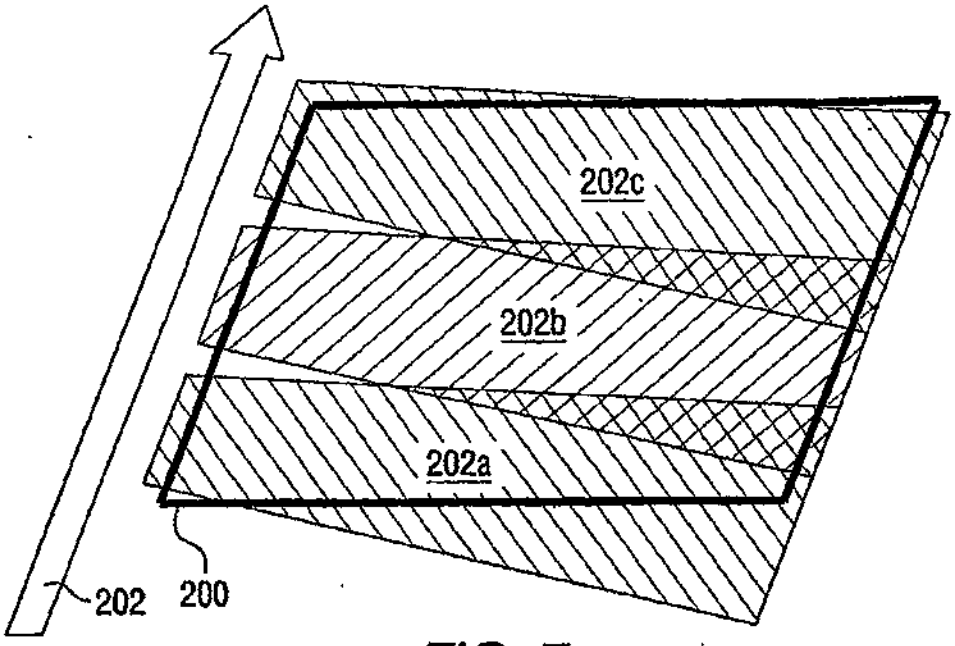


FIG. 7

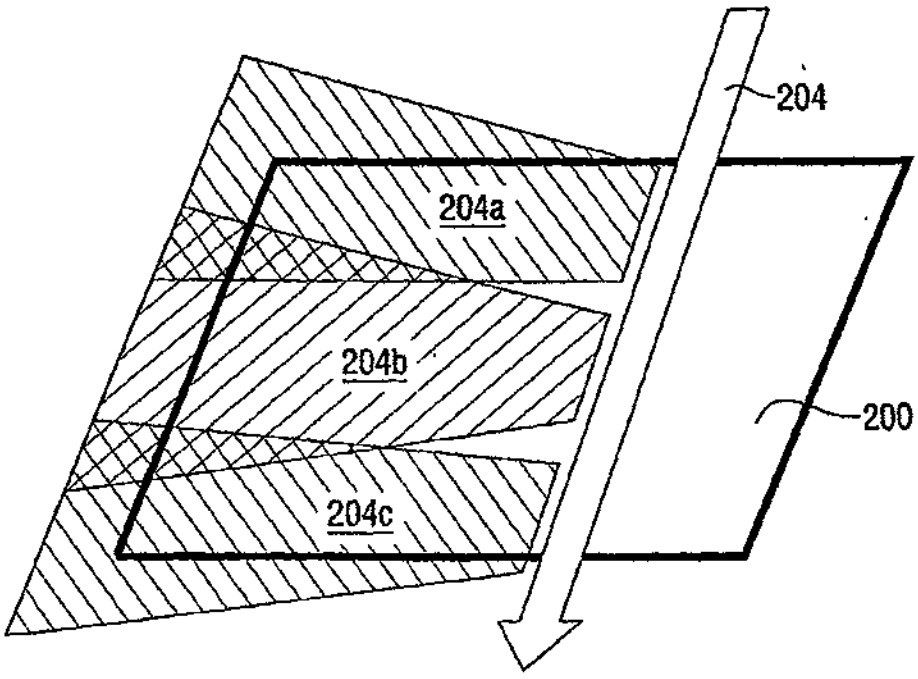


FIG. 8

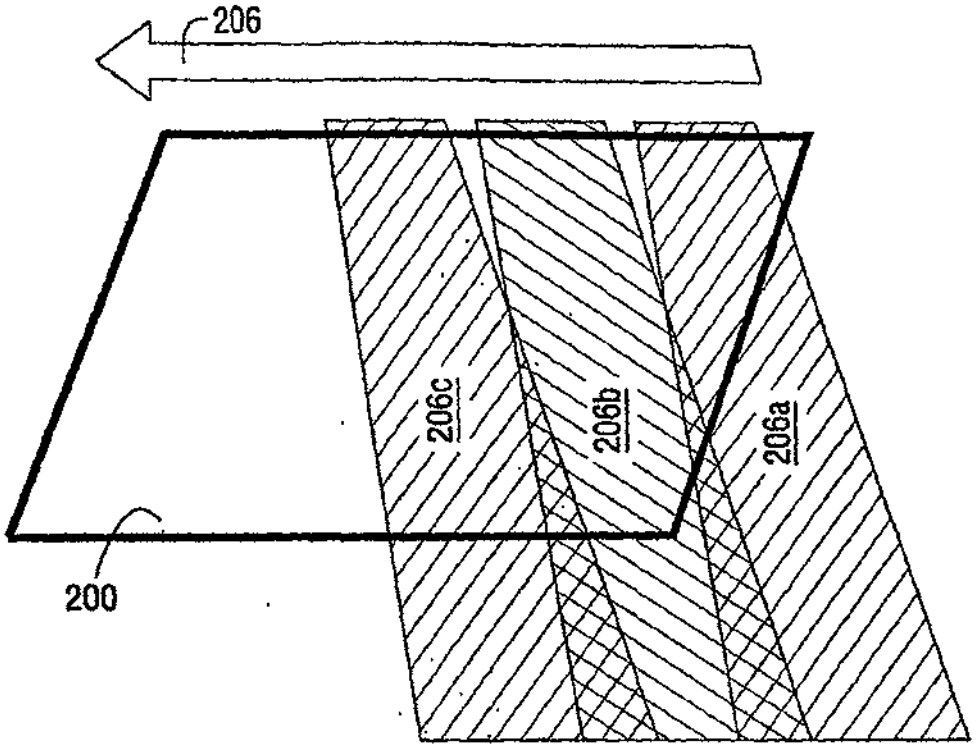


FIG. 9

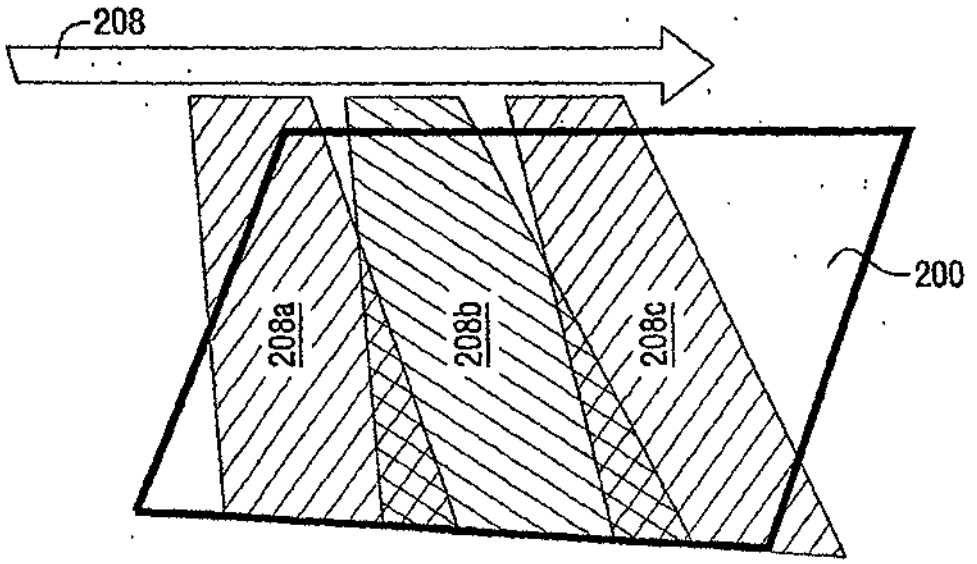


FIG. 10

(19) DANMARK

(10) DK/EP 1418402 T3



Patent- og
Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.[8]: *G 01 C 11/02 (2006.01)*

(45) Oversættelsen bekendtgjort den: 2006-10-23

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: 2006-06-21

(86) Europæisk ansøgning nr.: 03025702.6

(86) Europæisk indleveringsdag: 2003-11-07

(87) Den europæiske ansøgnings publiceringsdag: 2004-05-12

(30) Prioritet: 2002-11-08 US 425275 P

(84) Designerede stater: AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR

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(54) Benævnelse: Fremgangsmåde og apparat til at optage, geolokalisere og måle skråbilleder

(56) Fremdragne publikationer:
WO-A-99/18732
US-A- 3 153 784

Opfindelsen vedrører fotogrammetri. Opfindelsen angår især en fremgangsmåde og et apparat til at optage skråbilleder og til at måle objekter og afstande mellem objekter afbildet deri.

Fotogrammetri er læren om at foretage målinger af og med objekter, der er vist i fotos, navnlig luftfotos. Generelt indebærer fotogrammetri at tage billeder af terrestriske træk og udtrække data deraf, som f.eks. data indikerende relative afstande mellem og størrelser af objekter i billederne. Fotogrammetri kan også indebære sammenkobling af fotografier med andre data, såsom data repræsenterende breddegrad og længdegrad. I virkeligheden bliver billedet overlejret og gjort konformt med et særligt rumkoordinatsystem.

Konventionel fotogrammetri indebærer optagelse og/eller anskaffelse af orthogonale billeder. Billedtagningsindretningen, såsom et kamera eller sensor, bliver båret på et køretøj eller platform, såsom et fly eller en satellit, og bliver rettet mod et nadirpunkt, som ligger direkte under og/eller lodret nedad fra platformen. Punktet eller pixlen i billedet, der svarer til nadirpunktet er det eneste punkt/pixel, som er sandt orthogonalt for billedtagningsindretningen. Alle andre punkter eller pixler i billedet er i virkeligheden skrå i forhold til billedtagningsindretningen. Efterhånden som punkter eller pixler ligger i stigende afstand fra nadirpunktet, så ligger de i stigende grad skrå i forhold til billedtagningsindretningen, og ligeledes vil den målte jordprøveafstand (dvs. overfladeområdet der svarer til eller dækkes af hver pixel) også øges. Denne skråhed i et orthogonalt billede medfører, at træk i billedet bliver forvrænget, navnlig billeder, der er relativt langt fra nadirpunktet.

En sådan forvrængning fjernes eller kompenseres gennem en proces til orthokorrektion, som i bund og grund fjerner skråheden fra det orthogonale billede ved at fitte eller krumme hver pixel i et orthogonalt billede ned på et orthometrisk gitter eller koordinatsystem. Orthokorrektionsprocessen skaber et billede, hvori alle pixler har samme afstand til jorden og er orienteret mod nord. Således kan et vilkårligt punkt på et orthokorrigeret billede blive lokaliseret ved brug af et X-Y koordinatsystem, og så længe billedskaleringen er kendt, så kan længden og bredden af terrestriske træk såvel som den relative afstand mellem disse træk blive beregnet.

Skønt orthokorrektionsprocessen kompenserer i et vist omfang for skævvridninger i et orthogonalt billede, så indfører den andre uønskede forvrængninger og/eller unøjagtig-

heder i det orthokorrigerede orthogonale billede. Objekter afbildet i orthokorrigerede orthogonale billeder kan være svære at genkende og/eller identificere, fordi de fleste observatører ikke er vant til at betragte objekter, navnlig terrestriske træk, set ovenfra. For en utrænet observatør vil et orthokorrigeret billede have en række forvrængninger. Veje, der i virkeligheden er lige, fremstår krumme, og bygninger kan se ud til at hælde. Ydermere vil orthokorrigerede billeder rumme i det væsentlige ingen information med hensyn til højden af terrestriske elementer. Tolkningen og analysen af orthogonale og/eller orthokorrigerede orthogonale billeder bliver typisk udført af veltrænede analytikere, der har års specialtræning og erfaring i at kunne identificere objekter og terrestriske elementer i sådanne billeder.

Skønt orthogonale og orthokorrigerede billeder er nyttige i fotogrammetri, mangler de således information om højden af elementerne, der er afbildet deri, og kræver veltrænede analytikere til at tolke detaljer fra det, som billederne viser.

Skråbilleder er billeder, der optaget med billedtagningsindretningen sigtende eller pegende generelt til siden for eller nedad fra platformen, der bærer billedtagningsindretningen. I modsætning til orthogonale billeder viser skråbilleder siderne af terrestriske elementer, såsom huse, bygninger og/eller bjerge såvel som toppene deraf. Således bliver betragtning af et skråbillede mere naturligt og intuitivt end at betragte et orthogonalt eller orthokorrigeret billede, og selv tilfældige observatører vil være i stand til at genkende og tolke terrestriske elementer og andre objekter, der er afbildet i skråbilleder. Hver pixel i forgrunden af et skråbillede svarer til et relativt lille område af den afbillede overflade eller objekt (dvs. hver forgrundspixel har en relativt lille grundprøveafstand), mens hver pixel i baggrund svarer til et relativt stort område af den afbildede overflade eller objekt (dvs. hver baggrundspixel har en relativt stor grundprøveafstand). Skråbilleder optager et generelt trapezformet område eller billede af den undersøgte overflade eller objekt, hvorved forgrunden af trapezen har en betydelig mindre grundudsnitslængde (dvs. en højere opløsning) end baggrunden af trapezen.

Skråbilleder anses for at være af lille eller ingen nytte i fotogrammetri. Den traditionelle fremgangsmåde til at tvinge de forskellige størrelser forgrunds- og baggrundspixler af et skråbillede ind i en fælles størrelse for derved at vride billedet ned over et koordinatsystem giver en dramatisk forvrængning af skråbilledet og gør derved identifikation af objekter og udførelse af målinger af objekter, der er afbildet deri, til en

arbejdskrævende og unøjagtig opgave. Korrektion for terrænforskydning i et skråbillede gennem brug af en elevationsmodel vil yderligere forvrænge billederne og derved forøge det besvær, hvormed målinger kan foretages, og nøjagtigheden af enhver sådan måling reduceres.

Skønt skråbilleder anses for at være af lille eller ingen nytte i fotogrammetri, så er de lette at tolke og indeholder information vedrørende højden af de deri afbillede elementer. WO 99/18732 A1 beskriver et system og en fremgangsmåde til at optage, geolokalisere og måle skråbilleder omfattende en billedtagningsindretning, en geolokaliseringsindretning, et computersystem og et billed- og dataopsamlingsprogram, som knytter billeddata til geolokaliseringssignaldata.

Derfor behøves der på dette tekniske felt en fremgangsmåde og et apparat til fotogrammetri, der muliggør geolokation og nøjagtige målinger i skråbilleder.

Ydermere er der behov for en fremgangsmåde og et apparat til fotogrammetri, som muliggør måling af højder og relative højder af objekter i et billede.

Ydermere behøves en fremgangsmåde og et apparat til fotogrammetri, der benytter mere intuitive og naturlige billeder.

Ifølge opfindelsen er der tilvejebragt et system ifølge krav 1.

De ovennævnte og andre træk og fordele ved opfindelsen, og måden at opnå dem på, vil fremgå mere klart og forståeligt under henvisning til den efterfølgende beskrivelse af én udførelsesform for opfindelsen i forbindelse med de vedføjede tegninger, hvor:

fig. 1 viser en udførelsesform for en platform eller køretøj, der bærer et billedtagningssystem ifølge opfindelsen, og viser eksempler på orthogonale og skrå billeder taget dermed;

fig. 2 er et skematisk billede af billedtagningssystemet i fig. 1;

fig. 3 er et blokdiagram af billedtagningscomputersystemet i fig. 2;

fig. 4 viser en repræsentation af en som eksempel valgt outputdatafil fra billedtagningssystemet i fig. 1;

fig. 5 er et blokdiagram af en udførelsesform for et billedvisnings- og måltagnings-computersystem ifølge opfindelsen til at fremvise og tage målinger af og mellem objekter afbildet i billederne, der er optaget med billedtagningssystemet i fig. 1;

fig. 6 viser et eksempel på et billede vist med systemet i fig. 5 og illustrerer en udførelsesform for fremgangsmåden ifølge opfindelsen til måling af og mellem objekter afbildet i et sådant billede;

fig. 7 og 8 viser en udførelsesform for en fremgangsmåde til at tage skråbilleder ifølge opfindelsen;

fig. 9 og 10 viser en anden udførelsesform for en fremgangsmåde til at tage skrå-billeder ifølge opfindelsen.

Der benyttes ens referencetal til at indikere tilsvarende dele overalt i de forskellige billeder. De viste eksempler angiver en foretrukket udførelsesform for opfindelsen i en udførelsesform, og sådanne eksempler skal ikke opfattes som på nogen måde begrænsende for opfindelsens sigte.

Under henvisning til tegningerne, navnlig fig. 1, ses en udførelsesform for et apparat til at optage og geolokalisere skråbilleder ifølge opfindelsen. Apparatet 10 inkluderer en platform eller fartøj 20, der bærer billedtagnings- og geolokaliseringssystemet 30.

Platformen 20, som f.eks. et fly, et rumskib, raket, satellit eller et vilkårligt andet fartøj, bærer billedtagningssystemet 30 over et prædefineret område af og i én eller flere forudbestemte højder over overfladen 31, som f.eks. jordens omflade eller en vilkårlig anden udvalgt overflade. Platformen 20 er som sådan i stand til at foretage en kontrolleret bevægelse eller flyvning, enten bemandet eller ubemandet, langs en forud-defineret flyvelinie eller kurs gennem f.eks. jordens atmosfære eller det ydre rum. Billedtagningsplatformen 20 inkluderer et system til at generere og regulere strøm-energi (ikke vist), der inkluderer f.eks. én eller flere generatorer, brændselsceller, solpaneler og/eller batterier til at strømforsyne billedtagningssystemet 30.

Billedtagnings- og geolokaliseringssystemet 30 inkluderer, som det bedst ses i fig. 2, billedtagningsindretninger 32a og 32b, en global positioneringssystem (GPS) mod-tager 34, en inertinavigeringsenhed (INU) 36, en klokke 38, et gyroskop 40, et kompas 42 og en højdemåler 44, hvorved hver af disse er forbundet med billedtagnings-computersystemet 46.

Billedtagningsindretningerne 32a og 32b, som f.eks. traditionelle kameraer, digitale kameraer, digitale sensorer, ladningskoblede indretninger (CCD) eller andre egnede billedtagningsindretninger, er i stand til at tage billeder fotografisk eller elektronisk. Billedtagningsindretningerne 32a og 32b har kendte eller bestemmelige egenskaber inkluderende brændvidde, sensorstørrelse og billedformat, radiale og andre forvrængningsbetingelser, hovedpunktsforskydning, pixelpitch og orientering. Billedtagningsindretningerne 32a og 32b indsamler billeder og afgiver billeddatasignaler (IDS) 48a og 48b svarende til de optagne valgte billeder eller fotografier, og hvilke er lagret i billedtagningscomputersystemet 46, som det vil fremgå mere præcist beskrevet nedenfor.

Som det bedst ses af fig. 1, har billedtagningsindretningerne 32a og 32b respektive midterakser A_1 og A_2 og er monteret på platformen 20, således at akserne A_1 og A_2 hver står i en afbøjningsvinkel θ i forhold til et vandret plant P. Afbøjningsvinklen θ er stort set enhver skrå vinkel, men den vil fortrinsvis være ca. 20° til ca. 60° og er helst fra ca. 40° til ca. 50°.

GPS modtageren 34 modtager globalpositioneringssystemsignaler 52, der bliver transmitteret af én eller flere global positioneringssystemsatellitter 54. GPS signalerne 52 gør det på kendt måde muligt at fastsætte den præcise lokation af platformen 20 i forhold til overfladen 31. GPS modtageren 34 dekoder GPS signalerne 52 og afgiver lokationssignaler/data 56, der afhænger mindst delvis af GPS signaler 52, og som er indikative for den nøjagtige lokation af platformen 20 i forhold til overfladen 31. Lokationssignaler/data 56 svarende til hvert billede optaget af billedtagningsindretningerne 32a og 32b bliver modtaget og lagret i billedtagningscomputersystemet 46.

INU 36 er en traditionel inertinavigationsenhed, som er koblet til og bestemmer ændringer i hastigheden, inkluderende translations- og rotationshastighed, af billedtagningsindretningerne 32a og 32b og/eller platformen 20. INU 36 afgiver hastighedssignaler/data 58, der er indikative for sådanne hastigheder og/eller ændringer deri til billedtagningscomputersystemet 46, der lagrer hastighedssignaler/data 58 svarende til hvert billede, der er taget med billedtagningsindretningerne 32a og 32b, bliver modtaget og lagret af billedtagningscomputersystemet 46.

Klokken 38 holder en nøjagtig tidsmåling (valideringstid), som bliver anvendt til at synkronisere begivenheder i billedtagnings- og geolokaliseringssystemet 30. Klokken

38 tilvejebringer et tidsdata/klokkesignal 62, som indikerer det nøjagtige tidspunkt, hvor et billede er taget med billedtagningsindretningerne 32a og 32b. Tidsdata 62 bliver også tilvejebragt til og lagret i billedtagningscomputersystemet 46. Alternativt er klokken 38 udformet integralt med billedtagningscomputersystemet 46, som f.eks. med et klokkeprogram.

Et gyroskop 40 er et traditionelt gyroskop, der almindeligvis findes på fly og/eller i kommercielle navigationssystemer for fly. Gyroskopet 40 leverer signaler inkluderende pitch-signal 64, roll-signal 66 og yaw-signal 68, hvilke hver især er indikative for hældning, vipning og drejning af platformen 20. Pitch-signalet 64, roll-signalet 66 og yaw-signalet 58 svarende til hvert billede, der er taget med billedtagningsindretningerne 32a og 32b, bliver modtaget og lagret i billedtagningscomputersystemet 46.

Kompasset 42, f.eks. et traditionelt elektronisk kompas, indikerer orienteringen af platformen 20. Kompasset 42 afgiver et orienteringssignal/data 72, der er indikativt for orienteringen af platformen 20. Billedtagningscomputersystemet 46 modtager og lagrer orienteringssignalerne/dataene 72, som svarer til hvert billede optaget med billedtagningsindretningerne 32a og 32b.

Højdemåleren 44 indikerer højden af platformen 20. Højdemåleren 44 afgiver højdesignal/data 74, og billedtagningscomputersystemet 46 modtager og lagrer højdesignal/data 74, der svarer til hvert billede optaget med billedtagningsindretningerne 32a og 32b.

Det ses bedst af fig. 3, at billedtagningscomputersystemet 46, såsom f.eks. en traditionelt laptop PC, inkluderer en hukommelse 82, inputindretninger 84a og 84b, visningsmekanismen 86, og input og output (I/O) porte 88. Billedtagningscomputersystemet 46 eksekverer billed- og dataindsamlingsprogrammet 90, som er lagret i hukommelsen 82. Hukommelsen 82 lagrer også data, der er anvendt og/eller beregnet af billedtagningscomputersystemet 46 under driften deraf, og inkluderer f.eks. en non-volatile, kun læsbar hukommelse (ROM), en tilfældigadgangshukommelse (RAM), en harddiskhukommelse, udtagelige hukommelseskort og/eller andre egnede hukommelseslagerindretninger og/eller media. Inputindretninger 84a og 84b, såsom f.eks. en mus, tastatur, joystick eller andre lignende inputindretninger muliggør indtastning af data og interaktion mellem en bruger og programmet styret af billedtagningscomputersystemet 46. Visningsindretningen 86, såsom f.eks. et flydende krystal-

display (LCD) eller et katodestrålerør (CRT), viser information til brugeren af billedtagningscomputersystemet 46. I/O porte 88, såsom f.eks. serielle og parallelle dataindtastninger og outputporte, iværksætter indtastning og/eller udtræk af data til og fra billedtagningscomputersystemet 46.

Hver af de ovenfor beskrevne datasignaler er knyttet til billedtagningscomputersystemet 46. Mere præcist, så bliver billeddatasignaler 48, lokationssignaler 56, hastighedssignaler 58, tidsdatasignalet 62, pitch-, roll- og yaw-signaler 64, 66 og 68, orienteringssignalet 72 og højdesignalet 74 modtaget via I/O porte 88 på og lagret i hukommelsen 82 af billedtagningscomputersystemet 46.

Billedtagningscomputersystemet 46 aktiverer under drift billed- og dataindsamlingsprogrammet 90, som generelt styrer læsning/manipulering og lagring af de ovenfor beskrevne datasignaler. Mere præcist indlæser billed- og dataindsamlingsprogrammet 90 billeddatasignaler 48a og 48b og lagrer dem i hukommelsen 82. Hvert af lokationssignalerne 56, hastighedssignalerne 58, tidsdatasignalet 62, pitch, roll og yaw-signalerne 64, 66 og 68, orienteringssignalet 72 og højdesignalet 74, der repræsenterer de forhold, der eksisterede i det øjeblik, hvor et billede bliver anskaffet eller optaget med billedtagningsindretningerne 32a og 32b, og som svarer til de særlige billeddatasignaler 48a og 48b, der repræsenterer de optagne billeder, bliver modtaget af billedtagningscomputersystemet 46 gennem I/O portene 88. Billedtagningscomputersystemet 46, som aktiverer billed- og dataindsamlingsprogrammet 90 udsender billedtagningssignalet 92 til billedtagningsindretninger 32a og 32b for derved at få disse indretninger til at indsamle eller tage et billede ved forudbestemte lokationer og/eller ved forudbestemte intervaller, som afhænger mindst delvis af hastigheden af platformen 20.

Billed- og dataindsamlingsprogrammet 90 dekoder om nødvendigt og lagrer de førnævnte signaler i hukommelsen 82, og knytter datasignalerne sammen med tilsvarende billedsignaler 48a og 48b. Således kendes højden, orienteringen i form af roll, pitch og yaw og lokationen af billedtagningsindretningerne 32a og 32b i forhold til overfladen 31, dvs. længde- og breddegrad for hvert billede taget med billedtagningsindretningerne 32a og 32b.

Platformen 20 bliver styret eller på anden vis ført gennem en billedtagningsbane, som passerer over et særligt område af overfladen 31, som f.eks. et forudbestemt område

af overfladen af jorden eller en anden planet. Fortrinsvis vil billedtagningsbanen for platformen 20 ligge i rette vinkler i forhold til i det mindste én af grænserne for det udvalgte område. Antallet af gange platformen 20 og/eller billedtagningsindretningerne 32a og 32b passerer over det udvalgte område afhænger i det mindste delvis af størrelsen af området, og mængden af ønskede detaljer i de optagne billeder. De særlige detaljer af billedtagningsbanen for platformen 20 er beskrevet mere konkret nedenfor.

Når platformen 20 passerer over det udvalgte område så bliver en række skråbilleder taget med billedtagningsindretningerne 32a og 32b. Det vil være indlysende for en fagmand, at billeder bliver taget eller samlet ved hjælp af billedtagningsindretningerne 32a og 32b ved forudbestemte billedtagningsintervaller, der er afhængige i det mindste delvis af hastigheden af platformen 20.

Billeddatasignalerne 48a og 48b svarende til hvert indhentet billede bliver modtaget af og lagret i hukommelsen 82 i billedtagningscomputersystemet 46 via I/O porte 88. På tilsvarende måde bliver datasignalerne (dvs. billeddatasignaler 48, lokationssignaler 56, hastighedssignaler 58, tidsdatasignalet 62, pitch-, roll- og yaw-signaler 64, 66 og 68, orienteringssignal 72 og højdesignal 74) svarende til hvert optaget billede modtaget og lagret i hukommelsen 82 i billedtagningscomputersystemet 46 via I/O porte 88. Således bliver lokationen af billedtagningsindretningen 32a og 32b i forhold til overfladen 32 registreret i hukommelsen 82 med det nøjagtige tidspunkt, hvor hvert billede bliver taget og knyttet sammen med det tilsvarende optagne billede.

Det fremgår bedst af fig. 1, at lokationen af billedtagningsindretningerne 32a og 32b i forhold til jorden svarer til nadirpunktet N af det orthogonale billede 102. Således bliver *den nøjagtige geolokation af nadirpunktet N i det orthogonale billede 102 indikeret ved* lokationssignalet 56, hastighedssignaler 58, tidsdatasignalet 62, respektive pitch-, roll- og yaw-signaler 64, 66 og 68, retningssignalet 72 og højdesignalet 74. Når først nadirpunktet N i det orthogonale billede 102 er kendt, så kan geolokationen af en vilkårlig anden pixel eller punkt i billedet 102 blive bestemt på kendt måde.

Når billedtagningsindretningerne 32a og 32b optager skråbilleder, såsom skråbillederne 104a og 104b (fig. 1), *så vil lokationen af billedtagningsindretningerne 32a* og 32b i forhold til overfladen 31 blive indikeret på tilsvarende måde af lokationssignaler 56, hastighedssignaler 58, tidsdatasignalet 62, respektive pitch-, roll- og yaw-signaler 64, 66 og 68, retningssignal 72, højdesignal 74 og den kendte afbøjnings-

vinkel θ af primærakserne A_1 og A_2 af de respektive billedtagningsindretninger 32a og 32b.

Det bør især bemærkes, at en kalibreringsproces sætter billed- og datahentningsprogrammet 90 i stand til at indarbejde korrektionsfaktorer og/eller korrigere for enhver fejl, der er indbygget i eller skyldes billedtagningsindretningen 32, såsom f.eks. fejl som følge af kalibreret brændvidde, sensorstørrelse, radial forvrængning, hovedpunktsforskydning og orientering.

Billed- og datahentningsprogrammet 90 skaber og lagrer i hukommelsen 88 et eller flere outputbilled- og datafiler 120. Billed- og datahentningsprogrammet 90 vil især omdanne billeddatasignaler 48a, 48b og orienteringsdatasignaler (dvs. billeddatasignaler 48, lokationssignaler 56, hastighedssignaler 58, tidsdatasignal 62, respektive pitch-, roll- og yaw-signaler 64, 66 og 68, retningssignal 72 og højdesignal 74) til computerlæsbare, færdige billed- og datafiler 120. I fig. 4 ses en færdig billed- og datafil 120 at indeholde et antal optagne billedfiler I_1, I_2, ..., I_n svarende til optagne skråbilleder, og positionsdata C_{PD1}, C_{PD2}, ..., C_{PDn} svarende dertil.

Billedfilerne I_1, I_2, ..., I_n i billed- og datafilen 120 bliver lagret i hovedsageligt ethvert computerlæsbart billed- eller grafikfilformat, som f.eks. JPEG, TIFF, GIF, BMP eller PDF filformater, og bliver krydsrefereret med positionsdata C_{PD1}, C_{PD2}, ..., C_{PDn}, der *også lagres som computerlæsbare data. Alternativt bliver positionsdata* C_{PD1}, C_{PD2}, ..., C_{PDn} indlagt i de tilhørende billedfiler I_1, I_2, ..., I_n på kendt måde. Billeddatafiler 120 bliver derefter bearbejdet enten ved hjælp af billed- og datahentningsprogrammet 90 eller ved efterbehandling for at korrigere for fejl som f.eks. fejl, der skyldes flyvelinieafvigelser og andre fejl, som vil være kendt for en fagmand. Derefter vil billeddatafilerne 120 være klar til brug for at fremvise og foretage målinger af og mellem objekterne afbildet i de tagne billeder, inkluderende målinger af højderne af sådanne objekter.

Nu henvises til fig. 5, hvor der vises et billedvisnings- og målingscomputersystem 130, såsom f.eks. en traditionel bordcomputer eller en bærbar computer i en politibil, som indeholder en hukommelse 132, indtastningsindretninger 134a og 134b, en fremvisningsindretning 136 og en netværksforbindelse 138. Billedtagningscomputersystemet 130 aktiverer billedvisnings- og analyseprogrammet 140, som ligger lagret i hukommelsen 132. Hukommelsen 132 inkluderer f.eks. en ikke-flygtig ROM, en RAM,

harddiskhukommelse, udtagelige hukommelseskort og/eller andre egnede lagringsindretninger og/eller -media. Indtastningsindretningerne 134a og 134b som f.eks. en mus, et tastatur, et joystick eller andre lignende indtastningsindretninger, gør det muligt for en bruger at indtaste data og interagere med billedvisnings- og analyseprogrammet 140, der køres af billedvisnings- og målingscomputersystemet 130. Visningsindretningen 136 såsom en LCD skærm eller CRT skærm viser information til brugeren af billedvisnings- og målingscomputersystemet 130. Netværksforbindelsen 138 forbinder billedvisnings- og målingscomputersystemet 130 til et netværk (ikke vist) såsom f.eks. et LAN, WAN, internet og/eller WWW.

Under brug, og med henvisning til fig. 6, ses billedvisnings- og målingscomputersystemet 130, der afvikler billedvisnings- og analyseprogrammet 140, at åbne én eller flere outputbilled- og datafiler 120, der er blevet indlæst i hukommelsen 132, som f.eks. via netværksforbindelsen 138, et floppediskdrev, et udtageligt hukommelseskort eller andre passende midler. Ét eller flere af de optagne billeder I_1, I_2, ..., I_n af de færdige billed- og datafiler 120 bliver herefter vist som det viste skråbillede 142 under kontrol af billedvisnings- og analyseprogrammet 140. På næsten samme tid bliver én eller flere dataportioner C_{PD1}, C_{PD2}, ..., C_{PDn} svarende til det viste skråbillede 142 indlæst i en let tilgængelig del af hukommelsen 132.

Det bør især bemærkes, at det viste skråbillede 142 vises i det væsentlige som det blev optaget dvs. det viste billede 142 er ikke krummet eller fittet til noget koordinatsystem, og det viste billede 142 er heller ikke blevet orthokorrigeret. I stedet for at vride det viste billede 142 over et koordinatsystem for at muliggøre måling af objekter afbildet deri, så bestemmer billedvisnings- og analyseprogrammet 140 generelt kun de geolokationer for udvalgte pixel, som er nødvendige, eller bestemmer dem "i farten" gennem reference til dataportioner C_{PD1}, C_{PD2}, ..., C_{PDn} af de færdige billed- og datafiler 120 og beregning af positionen og/eller geolokationen af de udvalgte pixels under anvendelse af én eller flere projektionsformler, som det vil blive beskrevet mere detaljeret herefter.

Generelt foretager en bruger af visnings- og målingscomputersystemet 130 målinger af og mellem objekter afbildet i det viste skråbillede 142 gennem at vælge én af flere tilgængelige målemetoder tilvejebragt i billedvisnings- og analyseprogrammet 140. Brugeren vælger den ønskede målemetode gennem at gå ind i f.eks. en række rullegardinmenuer eller værktøjslinier M, eller via tastaturkommandoer. Målemetoderne,

som er tilvejebragt af billedvisnings- og analyseprogrammet 140, inkluderer f.eks. en afstandsmetode, der muliggør måling af afstanden mellem to eller flere udvalgte punkter, en arealmetode, der muliggør måling af det areal, som omsluttes af flere udvalgte og sammenknyttede punkter, en højdemetode, der muliggør måling af højden mellem to eller flere udvalgte punkter, og en elevationsmetode, der muliggør måling af ændringen i elevation af et udvalgt punkt i forhold til ét eller flere andre udvalgte punkter.

Efter valg af den ønskede målemetode vælger brugeren af billedvisnings- og analyseprogrammet 140 ved hjælp af én af indtastningsindretningerne 134a, 134b et startpunkt eller en startpixel 152 og et slutpunkt eller -pixel 154 på det viste billede 142, og billedvisnings- og analyseprogrammet 140 vil automatisk beregne og vise den søgte mængde som f.eks. afstanden mellem startpixlen 152 og slutpixlen 154.

Når brugeren vælger startpunkt/pixel 152, bliver geolokationen af det dertil svarende punkt på overfladen 31 ved hjælp af billedvisnings- og analyseprogrammet 140, som gennemfører én eller flere projektionsformler ved brug af dataportionerne C_{PD1}, C_{PD2}, ..., C_{PDn} af output billed- og datafilerne 120, der svarer til det konkret viste billede. Længde- og breddegrad af punktet på overfladen 31 svarende til pixlen 152 bliver derpå vist på skærmen 136 ved hjælp af billedvisnings- og analyseprogrammet 140 som f.eks. ved at overlejre længde- og breddegraden på det viste billede 142 tæt ved det udvalgte punkt/pixel eller i et pop-op vindue et andet sted på skærmen 136. Den samme fremgangsmåde gentages af brugeren vedrørende valget af slutpixel/punkt 154 og med billedvisnings- og analyseprogrammet 140 for udtrækning og visning af længde- og breddegradsinformationen.

Beregningen af afstanden mellem start- og slutpunkter/pixler 152, 154 sker ved at fastslå geolokationen af hver enkelt pixel 152, 154 "i farten". Dataportionerne C_{PD1}, C_{PD2}, ..., C_{PDn} af output billed- og datafilen 120 svarende til det viste billede bliver trukket frem, og geolokationen af punktet på overfladen 31 svarende til hver enkelt valgt pixel, bliver derpå bestemt. Forskellen mellem geolokationerne svarende til de valgte pixler bestemmer afstanden mellem pixlerne.

Som et eksempel på hvorledes geolokationen af et bestemt punkt eller pixel i det viste skråbillede 142 bliver bestemt, vil vi antage, at det viste billede 142 svarer til det orthogonale billede 104a (fig. 1). Brugeren af billedvisnings- og analyseprogrammet

140 vælger pixten 152, der for enkelthedens skyld svarer til centrum C (fig. 1) af skråbilledet 104a. Som vist i fig. 1 strækker linien 106 sig langs det vandrette plan G fra et punkt 108 deri, som ligger direkte under billedtagningsindretningen 32a, til centrum C af den nære rand eller kant 109 af skråbilledet 104a. Forlængelsen af primæraksen A_1 skærer gennem centrum C. Vinklen Ø er den vinkel, som dannes mellem linien 106 og forlængelsen af primæraksen A_1. Således bliver der dannet en trekant (uden referencenummer), der har toppunkter ved billedtagningsindretningen 132a, punktet 108 og centrum C, og har sider 106, forlængelsen af primæraksen A_1 og den lodrette (stiplede) linie 110 mellem punktet 108 og billedtagningsindretningen 32a.

Grundplanet G er et hovedsageligt vandret, plant eller ikke-skrånende grundplan (og som typisk vil have en elevation, der afspejler den gennemsnitlige elevation af terrænet), og derfor inkluderer den ovenfor beskrevne trekant en ret vinkel mellem siden/linien 110 og siden/linien 106. Fordi vinklen Ø og højden af billedtagningsindretningen 32a (dvs. længden af siden 110) er kendt, så bliver hypotenusen (dvs. længden af forbindelsen af primæraksen A_1) og den resterende anden side af den retvinklede trekant beregnet ved simpel geometri. Ydermere og fordi den nøjagtige position af billedtagningsindretningen 32a er kendt på tidspunktet, hvor billedet svarende til det viste billede 142a blev taget, vil også længde- og breddegraden af punktet 108 være kendt. Med kendskab til længden af siden 106, beregnet som beskrevet ovenfor, bliver det muligt at bestemme den nøjagtige geolokation af pixlen 154 svarende til centrum C af skråbilledet 104a ved hjælp af billedvisnings- og analyseprogrammet 140. Når først geolokationen af punktet svarende til pixlen 154 er kendt, så vil geolokationen af en vilkårlig anden pixel i det viste skråbillede 142 kunne bestemmes ved brug af de kendte kamerakarakteristika, såsom f.eks. brændvidde, sensorstørrelse og billedformat, radial og andet forvrængningsforhold, osv.

Afstanden mellem de to eller flere punkter svarende til to eller flere udvalgte pixler i det viste billede 142 beregnes ved hjælp af billedvisnings- og analyseprogrammet 140 gennem at fastlægge forskellen mellem geolokationerne af de udvalgte pixler under brug af kendte algoritmer, såsom f.eks. Gaussfordelingen og/eller forsvindingspunktmodellen, afhængigt af den valgte målemetode. Målingen af objekter afbildet eller optrædende i det viste billede 142 sker ved hjælp af en procedure, der i det væsentlige svarer til proceduren beskrevet ovenfor til måling af afstande mellem udvalgte pixler. F.eks. bliver længderne, bredderne og højderne af objekter, såsom f.eks. bygninger, floder, veje og i det væsentlige enhver anden geografisk eller

menneskeskabt struktur, der optræder i det viste billede 142, målt gennem at vælge en passende/ønsket målemetode og at vælge start- og slutpixlerne.

Det bør især bemærkes, at i afstandsmålemetoden i billedvisnings- og analyseprogrammet 140 bliver afstanden mellem de respektive start- og slutpunkter/pixler 152, 154 bestemt langs i det væsentlige en vilkårlig bane, som f.eks. en "lige-linie"-bane P1 eller en bane P2, som indebærer valg af mellempunkter/pixler og én eller flere "lige-linie"-segmenter, som er forbundet dertil.

Det bør også blive særligt bemærket, at afstandsmålemetoden i billedvisnings- og analyseprogrammet 140 bestemmer afstanden mellem udvalgte pixler ifølge en "gå på jorden" metode. Denne "gå på jorden" metode skaber en række indbyrdes forbundne liniesegmenter, repræsenteret kollektivt i form af banerne P1 og P2, som strækker sig mellem de udvalgte pixler/punkter, og som ligger på eller konformt med de plane plader af en række af indbyrdes forbundne facetter, der definerer et mosaikgrundplan. Mosaikgrundplanet, som vil blive mere detaljeret beskrevet nedenfor, følger nøje eller genskaber overfladens 31 terræn, og derfor følger banerne P1 og P2 også tæt overfladens 31 terræn. Ved at måle afstanden langs terrænet simuleret ved mosaikgrundplanet, så vil "gå på jorden" metoden tilvejebringe en mere nøjagtig og nyttig måling af afstanden mellem udvalgte punkter end den traditionelle fremgangsmåde, som krummer billedet ned over et system af "flad jord" eller gennemsnitselevationsplan og måler afstanden mellem udvalgte punkter langs den flade jord eller plan og ignorerer i det væsentlige variationer i terræn mellem punkterne.

F.eks. kan en entreprenør, der gør klar til at byde på en kontrakt om vejbelægning på en landevej over ujævnt eller bakket terræn bestemme den omtrentlige størrelse eller areal af vejen under brug af billedvisnings- og analyseprogrammet 140 og den dermed tilbudte "gå på jorden" målemetode. Entreprenøren kan opnå den omtrentlige mængde eller areal af vejen fra hans eller hendes eget kontor uden at skulle sende et undersøgelseshold til arbejdsstedet for at foretage de nødvendige målinger.

I modsætning til "gå på jorden" metoden ifølge opfindelsen, så indebærer "flad jord"- eller gennemsnitselevationsafstandsberegningsmetoderne medfødte unøjagtigheder, når der måles afstande mellem punkter og/eller objekter placeret i det ujævne terræn, og når der måles størrelser og/eller højder af objekter placeret på tilsvarende måde. Selv en behersket hældning eller stigning i den afbildede overflade resulterer i en

forskel i elevationen af nadirpunktet i forhold til hovedsageligt et vilkårligt andet punkt derpå. Hvis der igen henvises til fig. 1, så kan trekanten fremstillet af linien 106, forlængelsen af primæraksen A_1 og den lodrette (stiplede) linie 110 mellem punktet 108 og billedtagningsindretningen 32a ikke være en retvinklet trekant. Hvis dette er tilfældet, så vil enhver geometrisk beregning, som forudsætter, at trekanten er en retvinklet trekant, indeholde fejl, og sådanne beregninger ville blive reduceret til approksimationer som følge af selv en relativt svag gradient eller hældning mellem udvalgte punkter.

Hvis overfladen 31 f.eks. hælder opad mellem nadirpunktet N og centrum C nær ved randen eller kanten 108 af skråbilledet 104, så vil den anden linie 110 skære overfladen 31 før det punkt, hvorved sådan skæring ville optræde på en plan eller ikke-hældende overflade 31. Hvis centrum C ligger 15 fod (5 m) højere end nadirpunktet N og har en afbøjningsvinkel θ på 40°, så vil den beregnede lokation af centrum C ligge forskudt ca. 17,8 fod (5,3 m) uden korrektion for ændringen i elevation mellem punkterne.

Som beskrevet generelt ovenfor vil billedvisnings- og analyseprogrammet 140, for at kompensere i det mindste delvis for ændringer i elevation og deraf følgende unøjagtigheder i målingen af og mellem objekter i billedet 142, om nødvendigt referere til punkter i det viste billede 142 og på overfladen 31 til et forud beregnet mosaikmønstret eller facetteret grundplan 160 i fig. 6. Mosaikgrundplanet 160 inkluderer et antal individuelle facetter 162a, 162b, 162c, osv., som hver er indbyrdes forbundet med hinanden og er defineret af fire paspunkter (ikke refereret, men vist som punkter) med respektive elevationer. Hosliggende par facetter 162a, 162b, 162c osv., deler to paspunkter. Hver facet 162a, 162b, 162c, osv. har en tilhørende pitch og hældning. Mosaikgrundplanet 160 er skabt baseret på forskellige data og ressourcer som f.eks. topografiske kort og/eller digitale rastergrafikker, undersøgelsesdata og forskellige andre kilder.

Generelt bliver geolokationen af et udvalgt punkt på det viste billede 142 beregnet ved at fastlægge hvilke af facetterne 162a, 162b, 162c, osv., der svarer til det udvalgte punkt. Således bliver lokationen af det udvalgte punkt beregnet baseret på karakteristika, dvs. elevation, pitch og hældning, for facetterne 162a, 162b, 162c, osv., i stedet for at være baseret på en plan eller gennemsnitselevationsgrundplan. Fejl bliver kun indført, såfremt topografien af overfladen 31 og lokationen af det valgte punkt derpå

afviger fra den plane overflade af facetten 162a, 162b, 162c, osv., hvori det udvalgte punkt ligger. Den fejl kan reduceres gennem bilineær interpolation af elevationen af det valgte punkt i en bestemt af facetterne 162a, 162b, 162c, osv., og ved at anvende den interpolerede elevation i lokationsberegningen udført af billedvisnings- og analyse-programmet 140.

For at bruge mosaikgrundplanet 160 anvender billedvisnings- og analyseprogrammet 140 en modificeret "ray-tracing" eller strålesporingsalgoritme for at finde skæringspunktet for den projicerede stråle fra billedtagningsindretningen 32a eller 32b mod overfladen 31 og den mosaikformede grundplan 160. Algoritmen bestemmer ikke kun hvilken af facetterne 162a, 162b, 162c, osv., der gennemskæres af strålen, men også hvor i facetten skæringen sker. Ved brug af bilineær interpolation kan der fastlægges en ret præcis grundlokation. Med henblik på omvendt projektion bliver mosaikgrundplanet 160 anvendt til at finde grundelevationsværdien for den indtastede grundlokation; altså gennem brug af bilineær interpolation. Elevationen og lokationen bliver derefter anvendt til at projicere tilbage gennem en model af billedtagningsmekanismen 32a eller 32b for at bestemme, hvilken af pixlerne i det viste billede 142, der svarer til den givne lokation.

Navnlig og som et eksempel vil billedvisnings- og analyseprogrammet 140 udføre og/eller beregne geolokationen af punktet 164 gennem at overlejre og/eller fitte mosaikgrundplanen 160 til i det mindste en del 166 af overfladen 31, som f.eks. en bakke. Det bør bemærkes, at kun en mindre del af mosaikgrundplanen 160 og facetterne 162a, 162b, 162c, osv., deraf er vist sammen med profilen af delen 166 af overfladen 31. Som forklaret ovenfor bliver hver af facetterne 162a, 162b, 162c, osv., defineret af fire paspunkter, som hver især har respektive elevationer, og hver af facetterne har egen pitch og hældning. Den specifikke position af punktet 164 på planet/overfladen af facetten 162a, 162b, 162c, osv., hvori punktet 164 (eller dets projektion) ligger, bliver bestemt som beskrevet ovenfor.

Mosaikgrundplanen 160 bliver fortrinsvis skabt uafhængigt af driften af billedvisnings- og målingscomputersystemet 130 og billedvisnings- og analyseprogrammet 140. *Mosaikgrundplanen 160 udgør snarere en relativt simpel datatabel eller opslagstabel* 168 lagret i hukommelsen 132 af og/eller tilgængelig for billedvisnings- og målingscomputersystemet 130. Beregningsressourcerne, der kræves til at beregne lokationerne af alle paspunkterne af de mange facetter af en typisk grundplan, behøver

ikke nødvendigvis at ligge i billedvisnings- og målingscomputersystemet 130. Således er billedvisnings- og målingscomputersystemet 130 i stand til at blive brugt med og aktiveret fra en traditionel PC uden behov for yderligere beregningsressourcer.

Beregning af mosaikgrundplanet 160 uden for billedvisnings- og målingscomputersystemet 130 muliggør i det væsentlige, at et vilkårligt detaljeringsniveau kan blive indbygget i mosaikgrundplanet 160 dvs. størrelsen og/eller arealet, der dækkes af eller svarer til hver af facetterne 162a, 162b, 162c, osv., kan blive så stort eller så lille som ønsket, uden derved i væsentlig grad at forøge beregningstiden, forsinke driften af, eller i væsentlig grad forøge de ressourcer, som kræves af billedvisnings- og målingscomputersystemet 130 og/eller billedvisnings- og analyseprogrammet 140. Visnings- og målingscomputersystemet 130 kan derfor være et relativt basalt og ukompliceret computersystem.

Facetterne 162a, 162b, 162c, osv., har en ensartet størrelse overalt i et bestemt, vist billede 142. Hvis det viste billede 142 f.eks. svarer til et område, der er ca. 750 fod (225 m) bredt i forgrunden og ca. 900 fod (270 m) dybt, kan billedet blive nedbrudt i facetter, der er ca. 60 kvadratfod (4,6 m^2), hvorved der opnås ca. 15 facetter i bredden og 18 facetter i dybden. Alternativt ville størrelsen af facetterne 162a, 162b, 162c, osv., være ens med hensyn til antallet af pixler indeholdt deri, dvs. hver facet er det samme antal pixler i bredden og det samme antal pixler i dybden. Facetter i forgrunden af det viste billede 142, hvor pixeldensiteten er størst, ville derfor være dimensionsmæssigt mindre end facetterne i baggrunden af det viste billede 142, hvor pixeldensiteten er mindst. Fordi det er ønskeligt at foretage de fleste målinger i forgrunden af et vist billede, hvor pixeldensiteten er størst, så vil frembringelsen af facetter, der er ens med hensyn til antallet af pixler, som de indeholder, have fordelen ved at tilvejebringe mere nøjagtige målinger i forgrunden af det viste billede 142 i forhold til facetter, der er dimensionsmæssigt ens.

En anden fordel ved at benytte pixler som grundlag for at definere dimensioner af facetter 162a, 162b, 162c, osv., er, at lokationsberegningen (pixellokation i forhold til grundlokation) er relativt simpel. En bruger aktiverer billedvisnings- og målingscomputersystemet 130 for at vælge en pixel i en given facet, billedvisnings- og analyseprogrammet 140 slår op på data for facetten svarende til den valgte pixel, elevationen af den valgte pixel bliver beregnet som beskrevet ovenfor, og denne elevation anvendes i lokationsberegningen.

Generelt vil fremgangsmåden til at optage skråbilleder ifølge opfindelsen opdele et valgt område, som f.eks. et amt, i sektorer af hovedsagelig ensartet størrelse, f.eks. sektorer, med et areal på ca. én kvadratmil (2,6 km^2). Dette sker for at lette planlægningen af en flyveplan til at tage skråbilleder, som dækker hver tomme af det udvalgte område, og for at organisere og navngive sektorerne og/eller billederne deraf så der opnås let reference, lagring og genfinding (en proces, der er almindelig kendt som "sektorisering"). Fordi kanterne af ethvert geografisk område, såsom et amt, sjældent falder på lige kvadratmil-grænser, så tilvejebringer fremgangsmåden til at tage skråbilleder ifølge opfindelsen flere sektorer, end der er kvadratmil i det valgte område - hvor mange flere afhænger stort set af længden af amtsgrænserne såvel som, hvor lige eller takkede de er. Typisk vil man kunne forvente en ekstra sektor for hver to til tre mil (3-5 km) grænselinie. Hvis et amt eller andet valgt område er groft set 20 gange 35 mil (32 x 46 km) eller 700 kvadratmil (1800 km^2), så vil området blive opdelt i ca. 740 til 780 sektorer.

Fremgangsmåden til at tage skråbilleder ifølge opfindelsen vil generelt optage skråbilleder fra mindst to kompasretninger og tilvejebringer fuld dækning af det valgte område fra i det mindste disse to kompasretninger. Med henvisning til fig. 7 og 8 vises en første udførelsesform for en fremgangsmåde til at optage skråbilleder ifølge opfindelsen. For overskuelighedens skyld er fig. 7 og 8 baseret på et system, der kun har én billedtagningsindretning. Imidlertid er det klart, at der ville kunne anvendes to eller flere billedtagningsindretninger.

Billedtagningsindretningen optager et eller flere skråbilleder under hver passage over området 200. Billedtagningsindretningen, som beskrevet ovenfor, sigter under en vinkel ned over området 200 for at optage skråbilleder deraf. Området 200 bliver, på samme måde som en græsplane bliver klippet på, gennemfløjet i et frem- og tilbagegående mønster af den billedbærende indretning og/eller platform for at sikre dobbeltdækning af området 200.

Området 200 bliver især gennemfløjet af den billedbærende indretning 32 og/eller platformen 20 ved at følge en første linie 202 for derved at optage skråbilleder af dele 202a, 202b og 202c af området 200. Derpå bliver området 200 gennemfløjet af den billedbærende indretning 32 og/eller platformen 20 ved at følge en anden linie 204, der ligger parallelt med og i afstand fra og i en modsat retning af dvs. 180° fra, den første linie 202 for derved at optage skråbilleder af billederne 204a, 204b, 204c af området

200. Ved at sammenligne fig. 7 og 8 ses det, at en del 207 (fig. 8) af området 200 er dækket af billederne 202a-c, der er optaget fra en første retning eller perspektiv, og af billeder 204a-c, der er optaget fra en anden retning eller perspektiv. Som sådan vil midterdelen af området 200 være 100% dobbeltdækket. Det ovenfor beskrevne mønster for gennemflyvning eller passage over området 200 langs modsatte linier, der ligger parallelt med linierne 202 og 204, bliver gentaget indtil området 200 i sin helhed er helt dækket af mindst ét skråbillede optaget fra linier, der ligger parallelt med, i afstand fra hinanden, som dikteret af størrelsen af området 200, og i samme retning som linierne 202 og 204 for derved at udføre 100% dobbeltdækning af området 200 fra disse perspektiver/retninger.

Om ønsket og til at forøge detaljeringsgraden bliver området 200 dækket af to yderligere hhv. modsat rettede og parallelle tredje og fjerde linier 206 og 208, som ligger vinkelret på linierne 202 og 204, som vist i fig. 9 og 10. Området 200 bliver derfor overfløjet af den billedbærende indretning 32 og/eller platformen 20 ved at følge en tredje linie 206 for at tage skråbilleder af delene 206a, 206b og 206c af området 200 og derpå flyve langs en fjerde linie 208, der ligger parallelt med og i afstand fra og modsat rettet den tredje linie 206 for at tage skråbilleder af delene 208a, 208b og 208c af området 200. Dette mønster for overflyvning eller passage over området 200 langs modsat rettede linier, der ligger parallelt med linierne 206 og 208 bliver ligeledes gentaget indtil området 200 i sin helhed er helt dækket af mindst ét skråbillede optaget fra linier, som ligger parallelt med og i afstand fra (dikteret af størrelsen af området 200) og i samme retning som linierne 206 og 208 for derved at sikre 100% dobbeltdækning af området 200 fra de disse retninger/perspektiver.

Som beskrevet ovenfor vil den billedbærende indretning 32 og/eller platformen 20 overflyve eller passere over området 200 langs en forudbestemt linie. Imidlertid skal det forstås, at den billedbærende indretning og/eller platformen 20 ikke nødvendigvis flyver eller bevæger sig direkte over området 200, men vil snarere kunne passere eller flyve over et område op til, tæt ved eller endog lidt i afstand fra området 200 for at sikre, at den del af området 200, som bliver fotograferet, falder inden for billedtagningsfeltet for billedtagningsindretningen. Linien 202, der vises i fig. 7, er således en linie, der ikke går direkte hen over området 200 men alligevel tager skråbilleder deraf.

Ifølge opfindelsen er det muligt at optage billeder ved forskellige opløsningsforhold eller grundudsnitsafstande. Et første detaljeringsniveau, der herefter betegnes som nærområdeniveau, har en grundudsnitsafstand på f.eks. ca. to fod (60 cm) pr. pixel. For orthogonale nærområdebilleder forbliver grundudsnitafstanden hovedsageligt konstant over hele billedet. Orthogonale nærområdebilleder bliver taget med tilstrækkelig overlapning til at tilvejebringe stereodækning. For nærområdeskråbilleder varierer grundudsnitsafstanden fra f.eks. ca. én fod (30 cm) pr. pixel i forgrunden af billedet til ca. to fod (60 cm) pr. pixel i midten af billedet og til ca. fire fod (120 cm) pr. pixel i billedets baggrund. Nærområdeskråbilleder bliver taget med tilstrækkelig overlapning, således at hvert valgt område typisk dækkes af mindst to skråbilleder fra hver af de benyttede kompasretninger. Omtrent ti nærområdeskråbilleder bliver optaget pr. sektor.

Et andet detaljeringsniveau, der herefter omtales som et omegnsniveau, er betydeligt mere detaljeret end nærområdebillederne. Omegnsbillederne har en grundudsnitsafstand på f.eks. ca. seks tommer (15 cm) pr. pixel. For orthogonale omegnsbilleder forbliver grundudsnitsafstanden hovedsageligt konstant. Omegnsskråbilleder har en grundudsnitsafstand f.eks. fra ca. fire tommer (10 cm) pr. pixel i forgrunden af billedet til ca. seks tommer (15 cm) pr. pixel i midten af billedet og til ca. ti tommer (25 cm) pr. pixel i baggrunden af billedet. Omegnsskråbilleder bliver optaget med tilstrækkelig overlapning til, at hvert område typisk er dækket af mindst to skråbilleder fra hver kompasretning og således, at modsatte kompasretninger tilvejebringer 100% overlapning med hinanden. Der bliver pr. sektor taget ca. et hundrede skrå områdebilleder.

Det bør især bemærkes, at optagelse af nærområde- og/eller omegnsskråbilleder fra alle fire kompasretninger sikrer, at hvert punkt i billedet vil optræde i forgrunden eller den nederste del af i det mindste ét af de optagne skråbilleder, hvor grundudsnitsafstanden er mindst, og billeddetaljen er størst.

I den viste udførelsesform inkluderer billedtagnings- og geolokaliseringssystemet 30 et gyroskop, et kompas og en højdemåler. Det skal selvfølgelig stå klart, at billedtagnings- og geolokaliseringssystemet ifølge opfindelsen kan blive konfigureret på anden måde, for f.eks. at kunne udlede og/eller beregne højde, pitch, roll og yaw og kompasretningen fra GPS og INU signaler/data og derved gøre én eller flere af gyroskopet, kompasset eller højdemåleren overflødig.

I den viste udførelsesform er billedtagningsindretningerne placeret i en ens afbøjningsvinkel i forhold til et vandret plan. Imidlertid skal det forstås, at afbøjningsvinklerne for billedtagningsindretningerne ikke behøver at være ens.

I den viste udførelsesform eksekverer billedtagningscomputersystemet billed- og datahentningsprogrammet, der afgiver et fælles eller enkeltbilled-tagningssignal til billedtagningsindretningerne for derved at få disse indretninger til at hente eller tage et billede. Imidlertid skal det forstås, at opfindelsen alternativt kan konfigureres til separat at få billedtagningsindretningerne til at tage billeder på forskellige tidspunkter og/eller ved forskellige intervaller.

I den viste udførelsesform for fremgangsmåden ifølge opfindelsen tages skråbilleder for at tilvejebringe dobbeltdækning af et valgt område fra linier/perspektiver, der ligger hovedsageligt modsat hinanden dvs. 180° i forhold til hinanden. Imidlertid skal det forstås, at fremgangsmåden ifølge opfindelsen alternativt kan konfigureres til at tilvejebringe dobbeltdækning ved hjælp af linier/perspektiver, der generelt og/eller i det væsentlige ligger vinkelret i forhold til hinanden.

Skønt opfindelsen er blevet beskrevet i forbindelse med et foretrukket design, så kan opfindelsen blive yderligere modificeret inden for rammerne af kravene. Denne beskrivelse er derfor tænkt at omfatte enhver ækvivalent til de heri beskrevne strukturer og elementer. Ydermere er beskrivelsen beregnet til at omfatte enhver variation, brug eller tilpasning af opfindelsen, som benytter de heri beskrevne generelle principper. Ydermere er beskrivelsen tænkt at skulle omfatte enhver fravigelse fra den heri beskrevne sagsgenstand, som vil ligge inden for kendt eller almindelig praksis på fagområdet, og som falder inden for grænserne af de vedføjede krav.

PATENTKRAV

1. Computersystem til at vise, geolokalisere og foretage målinger baseret på optagne skråbilleder, omfattende:
   - et computersystem (130) med en hukommelse (132)
   - en billed- og datafil (120), som kan benyttes af systemet (130) og inkluderer en mængde af billedfiler svarende til et stort antal optagne skråbilleder, hvilken billed- og datafil (120) yderligere inkluderer positionsdata svarende til de mange billedfiler, og
   - et billedvisnings- og analyseprogram (140) aktiveret af systemet (130) til at læse billed- og datafilen (120) og vise i det mindste en del af de optagne skråbilleder som et vist skråbillede, hvilket billedvisnings- og analyseprogram (140) beregner geolokationerne af to eller flere udvalgte punkter i det viste skråbillede baseret i det mindste delvis på nævnte positionsdata, og billedvisnings- og analyseprogrammet (140) beregner en separationsafstand mellem to eller flere vilkårligt valgte punkter i det viste skråbillede, **kendetegnet ved**
   - en grundplansdatafil, der repræsenterer en mosaikgrundplan (160), hvilken grundplansdatafil leverer data til billedvisnings- og analyseprogram (140), og grundplansdatafilen repræsenterer en mosaikgrundplan, der ret tæt approksimerer mindst en del af terrænet, der er afbildet i de optagne skråbilleder, hvorved mosaikgrundplanen yderligere omfatter en mængde sammenknyttede billeder, mosaikgrundplanen omfatter yderligere en mængde sammenknyttede facetter (162a, 162b, 162c, ...), hvor hver af facetterne har hhv. en stigning (pitch) og en hældning, og grundplansdatafilen omfatter en mængde paspunkter, hvor hvert af paspunkterne har en højde og definerer hjørner af de sammenknyttede facetter (162a, 162b, 162c, ...), idet to af mængden af paspunkter deles af hver af de sammenknyttede facetter, og
   - billedvisnings- og analyseprogrammet (140) identificerer hvilke af mængden af facetter, der svarer til et valgt punkt på det viste skråbillede, og beregner en højde af det valgte punkt afhængigt i det mindste delvis af højden af paspunkterne for facetten, der hører til det valgte punkt, hvorved billedvisnings- og analyseprogrammet (140) benytter den beregnede højde til at beregne separationsafstanden mellem det valgte punkt og et eller flere yderligere punkter.

2. System ifølge krav 1, hvorved billedvisnings- og analyseprogrammet (140) kun beregner geolokationerne, når de behøves.
3. System ifølge krav 1 eller 2, hvorved billedvisnings- og analyseprogrammet (140) beregner en højde for et objekt i det viste skråbillede ved at beregne separationsafstanden mellem to eller flere udvalgte punkter.
4. System ifølge et af kravene 1-3, hvorved mosaikgrundplanen (160) er lagt oven på og tilpasset det viste skråbillede.
5. System ifølge et af kravene 1-4, hvorved billedvisnings- og analyseprogrammet (140) inkluderer brugervalgte målemodi, der er tilgængelige gennem mindst en rullegardinmenu, værktøjslinier og tastekommandoer.
6. System ifølge et af kravene 1-5, hvorved hvert billede blev optaget med en billedtagningsindretning (32a, 32b) og ved respektive billedtagningsbegivenheder, hvorved positionsdata for billede og datafil inkluderer:
   - tidsdata repræsenterende tidspunktet for hver billedtagningsbegivenhed;
   - lokationsdata repræsenterende lokationen af billedtagningsindretningen (32a, 32b) for hver billedtagningsbegivenhed;
   - orienteringsdata repræsenterende orienteringen af billedtagningsindretningen (32a, 32b) for hver billedtagningsbegivenhed;
   - korrektionsdata repræsenterende korrektionsfaktorer for billedtagningsindretningen (32a, 32b); og
   - elevationsdata repræsenterende en gennemsnitlig elevation af den med billedtagningsindretningen (32a, 32b) optagne overflade.
7. System ifølge krav 6, hvorved nævnte lokationsdata omfatter breddegrad, længdegrad og højde for billedtagningsapparatet (32a, 32b) ved hver billedtagningsbegivenhed.
8. System ifølge krav 6 eller 7, hvorved nævnte orienteringsdata omfatter roll, pitch og yaw samt retningen af billedtagningsindretningen (32a, 32b) ved hver billedtagningsbegivenhed.
9. System ifølge et af kravene 6-8, hvorved billedtagningsindretningen (32a, 32b) er et kamera, og nævnte korrektionsdata inkluderer mindst en brændvidde, sensorstørrelse, billedformat, hovedpunktsforskydning, forvrængning og pixel pitch (skærmopløsning).
10. System ifølge et af kravene 6-9, omfattende:
    - en indtastningsmekanisme (134a, 134b) til at vælge et startpunkt og et slutpunkt på det viste skråbillede; og

- billedvisnings- og analyseprogrammet (140) til fra datafilen at udtrække positionsdata svarende til startpunktet og til slutpunktet; til at give reference til grundplansdatafilen svarende til mosaikgrundplanen, der har adskillige facetter, hvor hver facet har hhv. stigning og hældning, hvorved mosaikgrundplanen svarer meget tæt til et terræn af det viste skråbillede; til at forbinde start- og slutpunkterne med liniesegmenter, hvorved liniesegmenterne svarer i form til stigning og hældning af facetterne for derved at følge terrænet; og til langs liniesegmenterne at beregne den lineære afstand mellem start- og slutpunkterne og derved tage hensyn til stigning og hældning af facetterne.

11. System ifølge et af kravene 1-10, hvorved billedvisnings- og analyseprogrammet (140) overlejrer mosaikgrundplanen på det viste skråbillede.

12. System ifølge krav 10 eller 11, omfattende:
    - indtastningsmekanismen (134a, 134b) til at vælge et eller flere mellempunkter på det viste skråbillede; og
    - billedvisnings- og analyseprogrammet (140) til fra datafilen at udtrække positionsdata svarende til nævnte et eller flere mellempunkter; til at forbinde hosliggende mellempunkter med hinanden, og til med liniesegmenter at forbinde start- og slutpunkterne med de hosliggende mellempunkter, hvorved liniesegmenterne svarer i form til stigning og hældning af facetterne for derved at følge terrænet; og til langs liniesegmenterne at beregne afstanden mellem start- og slutpunkterne.

13. System ifølge et af kravene 1-12, hvorved de adskillige facetter (162a, 162b, 162c, ...) hver svarer til ens områder af det viste skråbillede.

14. System ifølge et af kravene 1-13, hvorved de adskillige facetter (162a, 162b, 162c, ...) hver inkluderer ens antal pixels af det viste skråbillede.

15. System ifølge et af kravene 1-14, omfattende en indtastningsindretning (134a, 134b) til at vælge et eller flere mellempunkter på det viste skråbillede; og billedvisnings- og analyseprogrammet (140) til at udtrække positionsdata *svarende til mellempunkterne*.

16. System ifølge et af kravene 1-15, hvorved separationsafstanden omfatter en afstand mellem to eller flere valgte punkter, en højdeforskel mellem to eller flere valgte punkter, en forskel i elevation af to eller flere valgte punkter, og et område omgivet af mindst tre punkter.

17. System ifølge et af kravene 1-16, omfattende:

- en billedtagningsindretning (32a, 32b), hvilken indretning optager skråbilleder ved billedtagningsbegivenheder og afgiver billeddatasignaler svarende til de optagne billeder;
- mindst en geolokaliseringsindretning (34, ..., 44), som hver især afgiver et tilhørende mindst et geolokaliseringssignal, der hver især er indikativt for mindst en del af geolokationen af billedtagningsindretningen (32a, 32b) under hver billedtagningsbegivenhed; og
- et computersystem (46) til at modtage og lagre billeddatasignalerne og det mindst ene geolokaliseringssignal; og
- et billed- og dataindsamlingsprogram (90), der indlæser billeddata-signalerne og det mindst ene geolokaliseringssignal, hvorved programmet (90) udstyrer hvert billeddatasignal med et tilsvarende af de nævnte mindst ene geolokaliseringssignal for hver billedtagningsbegivenhed.

18. System ifølge krav 17, hvorved den mindst ene geolokaliseringsindretning henholdsvis det mindst ene geolokaliseringssignal omfatter:
- en klokke (38), der til billedtagningscomputersystemet (46) afgiver tidsdata-signaler indikerende et tidspunkt for hver billedtagningsbegivenhed;
- en global positioneringssystem (GPS) modtager (34), der modtager GPS signaler og til billedtagningscomputersystemet (46) afgiver lokationsdata-signaler indikerende længdegrad og breddegrad for billedtakningsindretningen (32a, 32b) ved hver billedtagningsbegivenhed;
- en inertinavigationsenhed (36), der til billedtagningscomputersystemet (46) afgiver hastighedsdatasignaler indikerende en hastighed for billedtagnings-indretningen (32a, 32b) ved hver billedtagningsbegivenhed;
- et gyroskop (40) der til billedtagningscomputersystemet (46) afgiver et pitch signal, et roll signal og et yaw signal indikerende hhv. pitch, roll og yaw for billedtagningsindretningen (32a, 32b) ved hver billedtagningsbegivenhed;
- et kompas (42) der til billedtagningscomputersystemet (46) afgiver retnings-datasignaler, der er indikative for retningen af billedtagningsindretningen (32a, 32b) ved hver billedtagningsbegivenhed; og
- en højdemåler (44) der til billedtagningscomputersystemet (46) afgiver højde-datasignaler, der er indikative for højdeangivelsen for billedtagnings-indretningen (32a, 32b) ved hver billedtagningsbegivenhed.

19. System ifølge krav 17 eller 18, yderligere omfattende korrektionsdata, der er indikative for egenskaber ved billedtagningsindretningen (32a, 32b) inklude-rende brændvidde, sensorstørrelse, radial forvrængning, hovedpunkts-

forskydning og orientering, hvorved billed- og dataopsamlingsprogrammet (90) benytter nævnte korrektionsdata til at korrigere optagne billeder.

20. System ifølge et af kravene 17-19, yderligere omfattende en outputdatafil oprettet af billed- og dataopsamlingsprogrammet (90), hvilken outputdatafil inkluderer adskillige billedfiler og positionsdata svarende til hver enkelt af de adskillige billedfiler.

21. System ifølge et af kravene 17-20, yderligere omfattende en platform (20), der bærer billedtagningsindretningen (32a, 32b) i en forudbestemt afstand over en udvalgt overflade.

22. System ifølge krav 21, hvorved billedtagningsindretningen (32a, 32b) tager skråbilleder af et udvalgt område i form af skråbilleder ved at:

- underinddele det valgte område (200) i et antal sektorer (202a, 202b, 202c);
- at styre platformen (20) langs en første linie (202) for derved at fokusere på en eller flere målsektorer med billedtagningsindretningen (32a, 32b);
- at med billedtagningsindretningen (32a, 32b) optage et eller flere skråbilleder for derved i sin helhed at dække målsektoren med skråbilleder taget fra en første synsvinkel;
- at styre platformen (20) langs en anden linie (204) for derved at fokusere på målsektorerne;
- at med billedtagningsindretningen (32a, 32b) optage et eller flere skråbilleder for derved i sin helhed at dække hver målsektor med skråbilleder taget fra en anden synsvinkel;
- at gentage styre- og optagefaserne langs linier, der ligger i det væsentlige parallelt med og adskilt fra den første og anden linie (202, 204) og at optage et eller flere skråbilleder for derved i sin helhed at dække alle målsektorerne med skråbilleder taget fra både den første og anden synsvinkel; og
- at registrere positionsdata, der er indikative for en geolokation af billedtagningsindretningen (32a, 32b) ved hver billedtagningsbegivenhed.

23. System ifølge krav 22, hvorved den anden linie (204) er hovedsageligt parallel med og 180° fra den første linie (202).

24. System ifølge krav 23, hvorved den anden linie (204) også befinder sig i afstand fra den første linie (202).

25. System ifølge et af kravene 22-24, hvorved:

- platformen (20) bliver styret langs en tredje linie (206) for derved at fokusere på en eller flere målsektorer med billedtagningsindretningen (32a, 32b); hvorved den tredje linie ligger hovedsageligt vinkelret på den første og anden linie (202, 204);
- billedtagningsindretningen (32a, 32b) optager et eller flere skråbilleder for derved i sin helhed at dække hver målsektor med skråbilleder taget fra en tredje synsvinkel; hvorved
- platformen (20) bliver styret og billedtagningsindretningen (32a, 32b) optager skråbillederne langs linier, der ligger hovedsageligt parallelt med og i afstand fra den tredje linie (206); og
- billedtagningsindretningen (32a, 32b) optager et eller flere skråbilleder for derved i sin helhed at dække hver af de mange målsektorer med skråbilleder taget fra den tredje synsvinkel.

26. System ifølge krav 25, hvorved:

- platformen (20) bliver styret langs en fjerde linie (208) for derved at fokusere på en eller flere målsektorer med billedtagningsindretningen (32a, 32b); hvorved den fjerde linie (208) ligger hovedsageligt parallelt med den tredje linie (206) og 180° fra den tredje linie (206);
- billedtagningsindretningen (32a, 32b) optager et eller flere skråbilleder for derved i sin helhed at dække hver målsektor med skråbilleder taget fra en fjerde synsvinkel; hvorved
- styre- og optagefaserne gentages langs linier, der ligger i det væsentlige parallelt med og adskilt fra den fjerde linie (208), for at optage et eller flere skråbilleder for derved i sin helhed at dække alle målsektorerne med skråbilleder taget fra den fjerde synsvinkel.

27. System ifølge krav 26, hvorved den fjerde linie (208) også ligger i afstand fra den tredje linie (206).

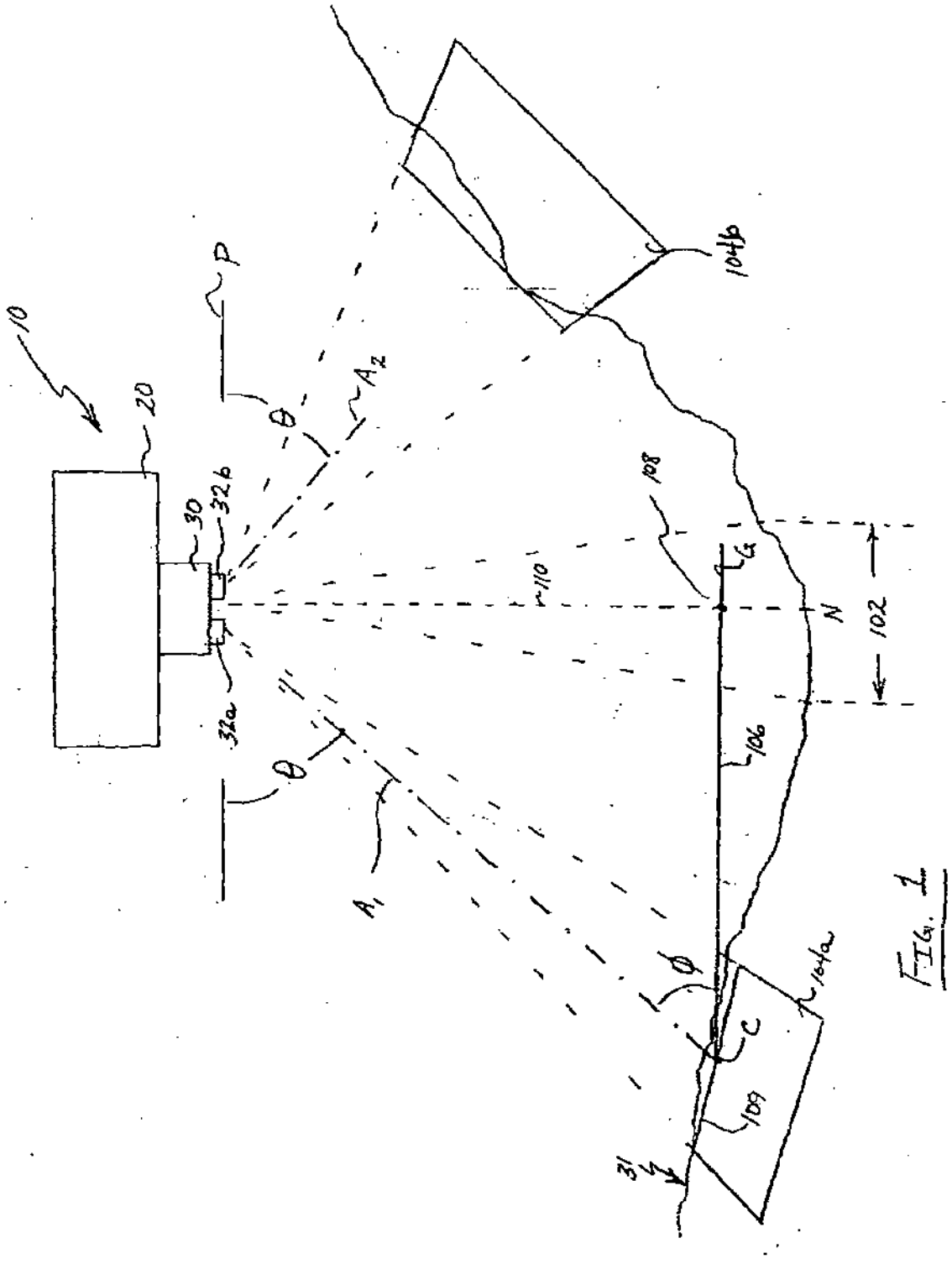


Fig. 1

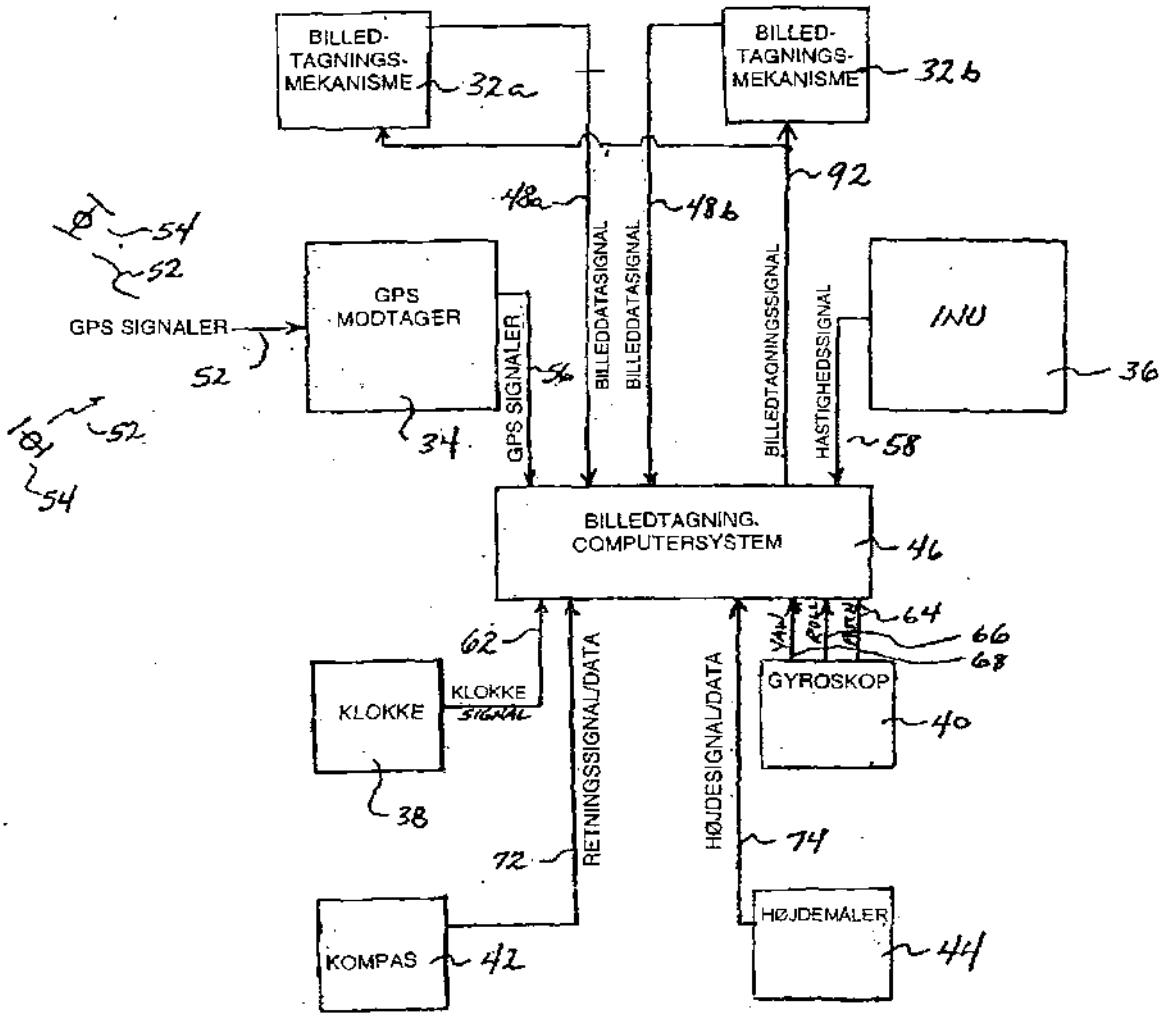

BILLED-TAGNINGS-MEKANISME
32a
BILLED-TAGNINGS-MEKANISME
32b
92
48a
48b
54
52
GPS SIGNALER
52
GPS MODTAGER
34
GPS SIGNALER
56
BILLEDDATASIGNAL
BILLEDDATASIGNAL
BILLEDTAGNINGSSIGNAL
HASTIGHEDSSIGNAL
58
INU
36
52
54
BILLEDTAGNING-COMPUTERSYSTEM
46
62
64
66
68
KLOKKE
KLOKKE SIGNAL
38
GYROSKOP
40
RETNINGSSIGNAL/DATA
72
HØJDESIGNAL/DATA
74
KOMPAS
42
HØJDEMÅLER
44

FIG. 2

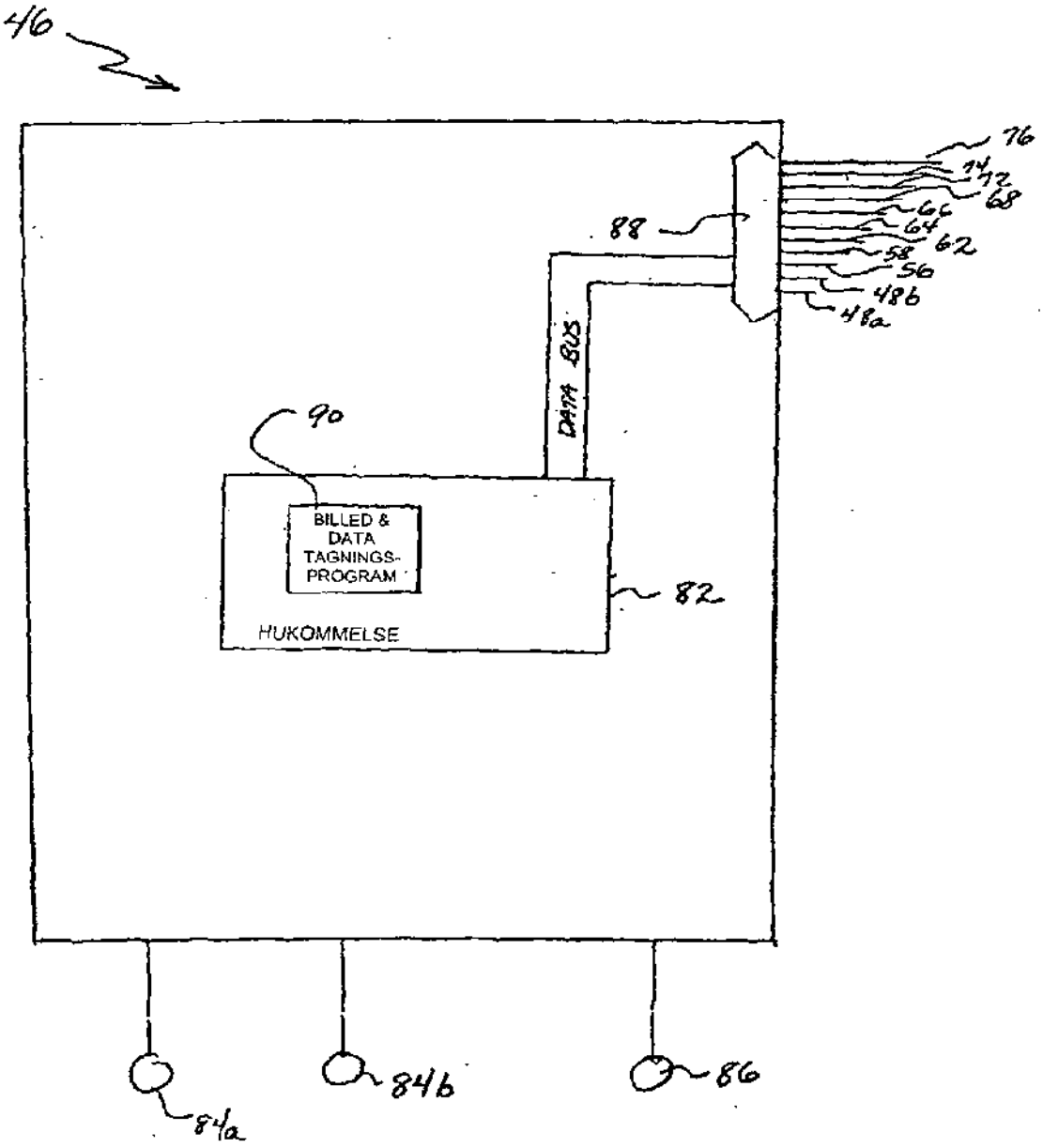

46
76
74
72
68
66
64
62
58
56
48b
48a
88
DATA BUS
90
BILLED & DATA TAGNINGS-PROGRAM
HUKOMMELSE
82
84a
84b
86

FIG. 3

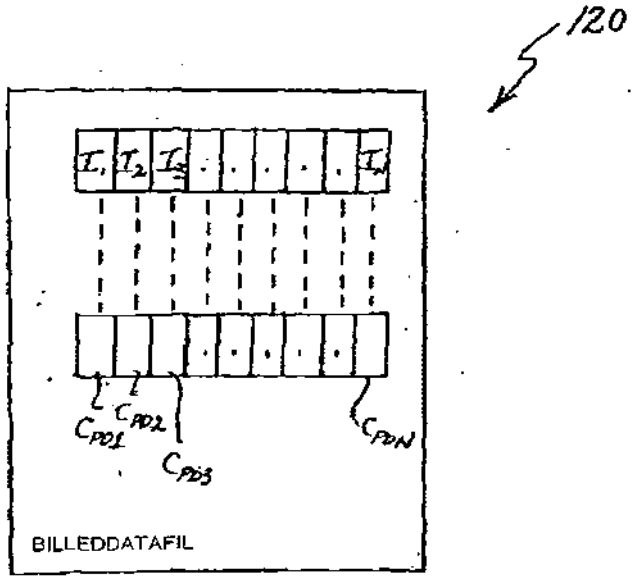


FIG. 4

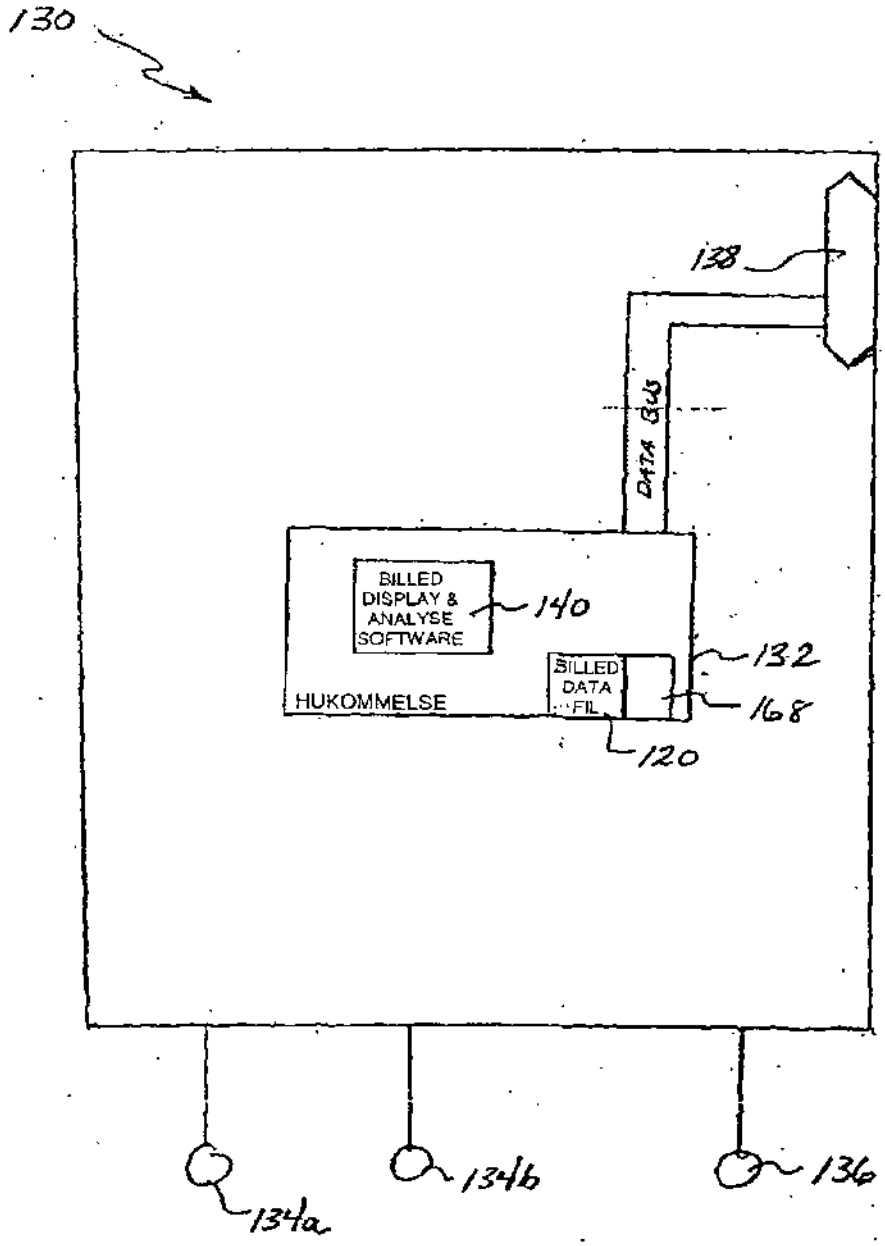

130
138
DATA BUS
BILLED DISPLAY & ANALYSE SOFTWARE
140
132
BILLED DATA FIL
168
HUKOMMELSE
120
134a
134b
136

FIG. 5

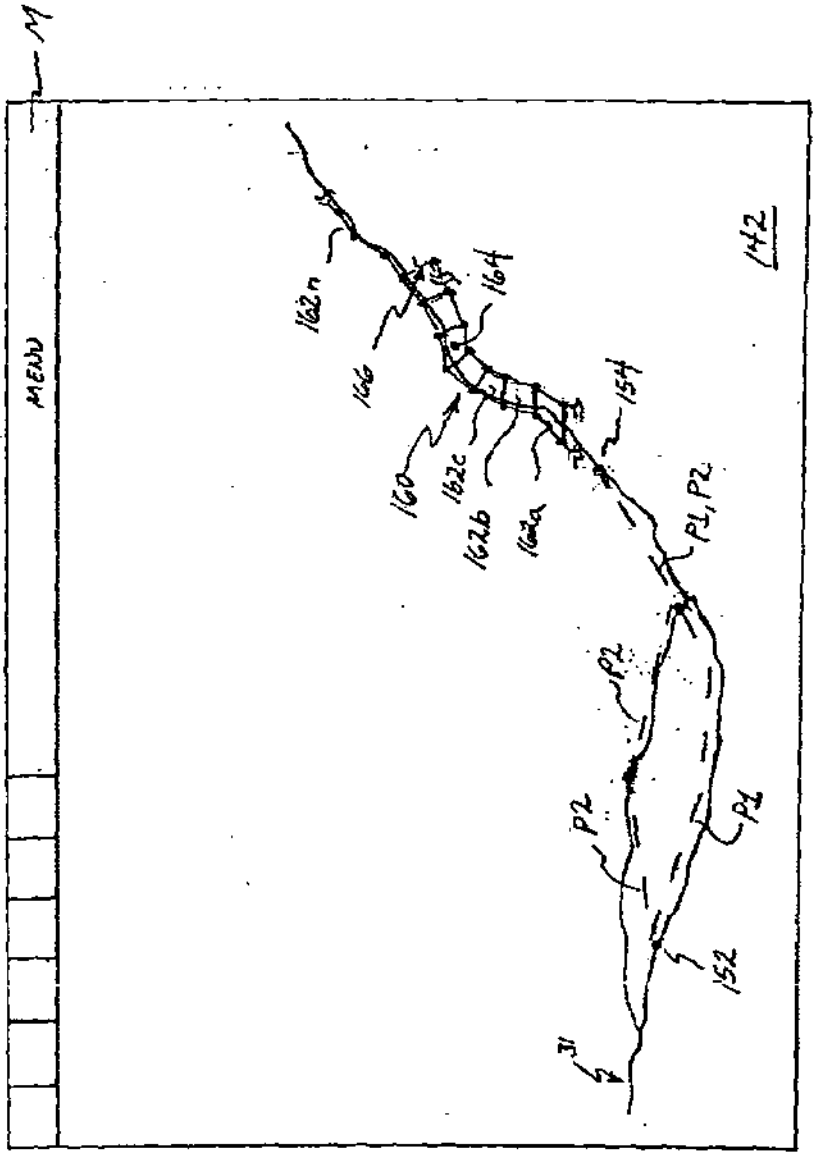

MEND
M
162n
166
164
160
162c
162b
162a
154
142
P1, P2
P2
P2
P1
152
31

FIG. 6

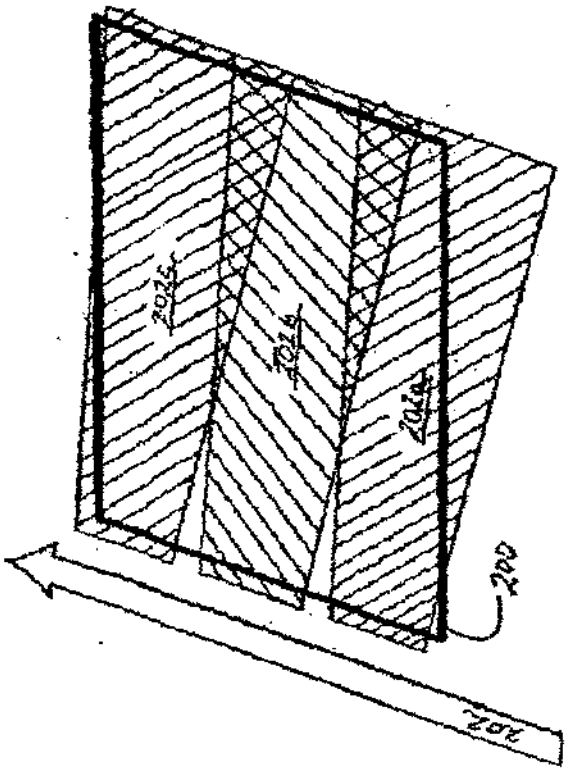


Fig. 7

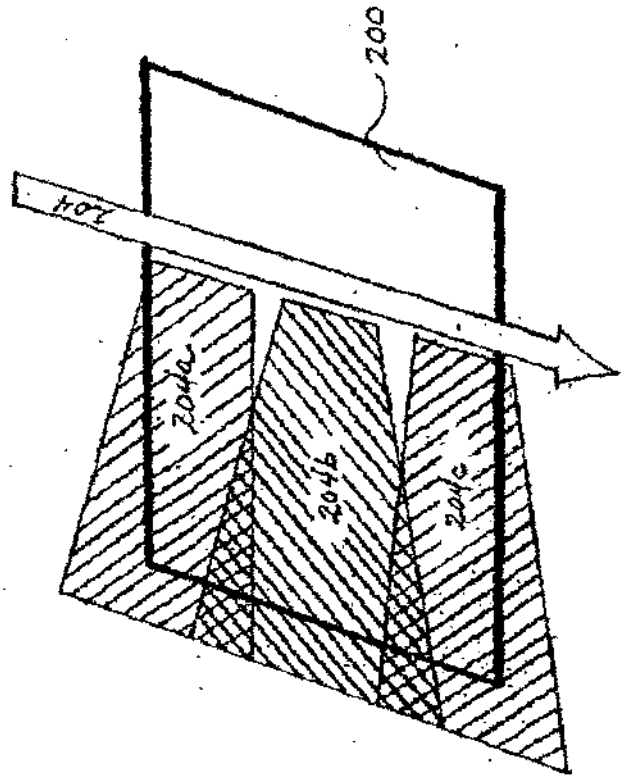


Fig. 6

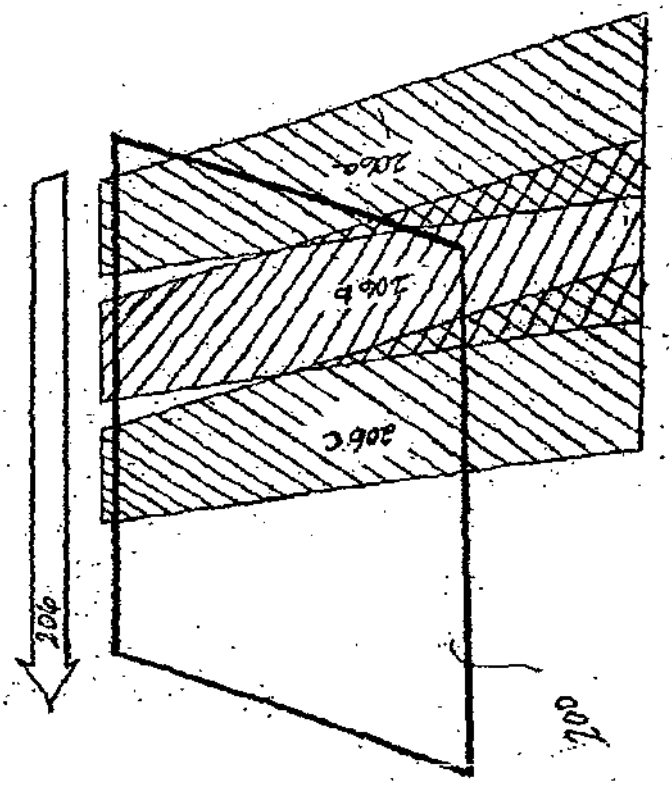


Fig. 9

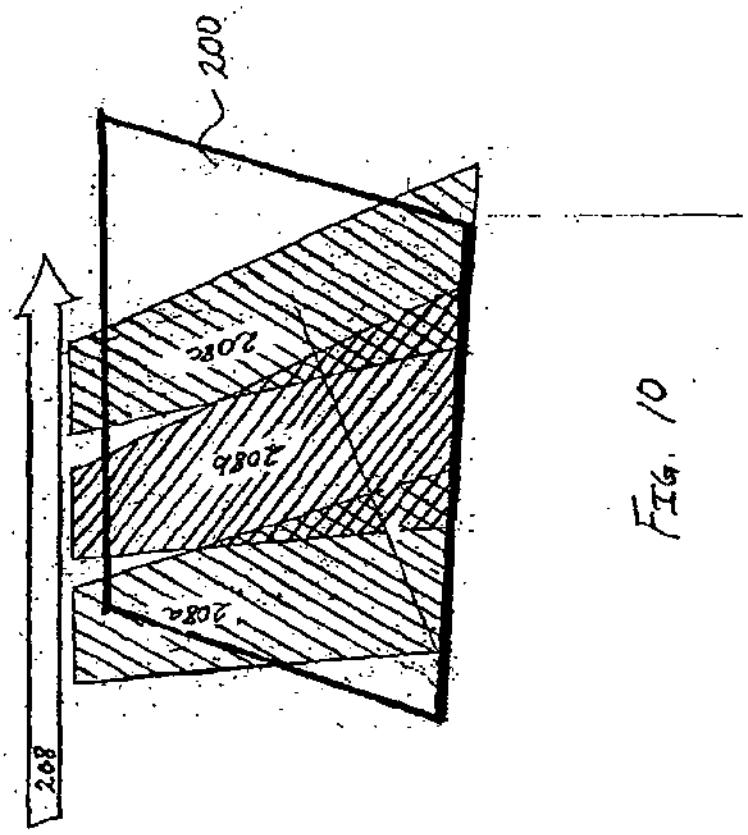


FIG. 10

(19) Bundesrepublik Deutschland
Deutsches Patent- und Markenamt

(10) **DE 603 06 301 T2** 2006.11.16

(12) # Übersetzung der europäischen Patentschrift

(97) **EP 1 418 402 B1**
(21) Deutsches Aktenzeichen: **603 06 301.2**
(96) Europäisches Aktenzeichen: **03 025 702.6**
(96) Europäischer Anmeldetag: **07.11.2003**
(97) Erstveröffentlichung durch das EPA: **12.05.2004**
(97) Veröffentlichungstag der Patenterteilung beim EPA: **21.06.2006**
(47) Veröffentlichungstag im Patentblatt: **16.11.2006**

(51) Int Cl.[8]: ***G01C 11/02*** (2006.01)

(30) Unionspriorität:
425275 P **08.11.2002** **US**

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WUESTHOFF & WUESTHOFF Patent- und Rechtsanwälte, 81541 München

(84) Benannte Vertragsstaaten:
AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LI, LU, MC, NL, PT, RO, SE, SI, SK, TR

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(54) Bezeichnung: **Verfahren und Gerät zur Erfassung, Geolokalisierung und Vermessung schräg aufgenommener Bilder**

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Die Übersetzung ist gemäß Artikel II § 3 Abs. 1 IntPatÜG 1991 vom Patentinhaber eingereicht worden. Sie wurde vom Deutschen Patent- und Markenamt inhaltlich nicht geprüft.

Beschreibung

QUERBEZUG ZU VERWANDTEN ANMELDUNGEN

[0001] Diese Anmeldung beansprucht die Priorität der provisorischen US-Patentanmeldung 60/425,275, angemeldet am 08. November 2002.

TECHNISCHES GEBIET

[0002] Die vorliegende Erfindung betrifft die Bildmessung bzw. Photogrammetrie. Im Besonderen betrifft die vorliegende Erfindung ein Verfahren und eine Vorrichtung zum Aufnehmen schräger Bilder und zum Messen der Objekte und Abstände zwischen den darin abgebildeten Objekten.

HINTERGRUND

[0003] Die Bildmessung ist die Wissenschaft des Durchführens von Messungen von und zwischen Objekten, die in Bildern dargestellt sind, insbesondere in Luftaufnahmen. Allgemein verwendet die Bildmessung ein Aufnehmen von Bildern erdgebundener Merkmale und ein Ableiten von Daten daraus, wie beispielsweise von Daten, welche relative Abstände zwischen und Größen von Objekten innerhalb der Bilder anzeigen. Die Bildmessung kann auch ein Koppeln der Fotografien mit anderen Daten umfassen, wie beispielsweise Daten, welche einem Breitengrad und einem Längengrad entsprechen. Im Effekt wird das Bild einem bestimmten räumlichen Koordinatensystem überlagert und diesem angepasst.

[0004] Herkömmliche Bildmessung umfasst das Aufnehmen und/oder Erfassen orthogonaler Bilder. Die Bildaufnahmevorrichtung, wie beispielsweise eine Kamera oder ein Sensor, wird von einem Fahrzeug oder einer Plattform getragen, wie beispielsweise einem Flugzeug oder einem Satelliten, und ist auf einen Fusspunkt ausgerichtet, welcher direkt unter und/oder vertikal nach unten von dieser Plattform aus liegt. Der Punkt oder Bildpunkt (Pixel) in dem Bild, welcher dem Fusspunkt entspricht, ist der einzige Punkt/Bildpunkt, der tatsächlich orthogonal zur Bildaufnahmevorrichtung liegt. Alle anderen Punkte oder Bildpunkte in dem Bild sind tatsächlich schräg bezüglich der Bildaufnahmevorrichtung. Wenn die Punkte oder Bildpunkte sich zunehmend von dem Fusspunkt entfernen, werden sie immer schräger relativ zur Bildaufnahmevorrichtung, und auch der Grundabtastabstand (d. h., die Größe der Oberfläche, die jedem Bildpunkt zugehörig ist oder diesen abdeckt) erhöht sich. Eine solche Schrägheit in einem orthogonalen Bild führt dazu, dass die Merkmale in dem Bild verzerrt werden, insbesondere Abbilder relativ weit vom Nadir bzw. Fusspunkt entfernt.

[0005] Eine solche Verzerrung wird bereinigt oder kompensiert durch den Vorgang des Geradeziehens, welcher im Wesentlichen die Schrägheit aus dem orthogonalen Bild durch Anpassen oder Verformen jedes Bildpunkts eines orthogonalen Bildes auf ein orthogonales Gitter oder Koordinatensystem beseitigt. Dieser Ablauf des Geradeziehens erzeugt ein Bild, in dem alle Bildpunkte den gleichen Grundabtastabstand aufweisen und nach Norden ausgerichtet sind. Daher kann jeder Punkt auf einem geradegezogenen Bild unter Verwendung eines X,Y-Koordinatensystems lokalisiert werden, und, so lange der Bildmaßstab bekannt ist, können die Länge und Breite erdbezogener Merkmale auch als relativer Abstand zwischen solchen Merkmalen berechnet werden.

[0006] Obwohl der Ablauf des Geradeziehens bis zu einem gewissen Grad schräge Verzerrungen in einem orthogonalen Bild kompensiert, führt er andere unerwünschte Verzerrungen und/oder Ungenauigkeiten in das geradegezogene orthogonale Bild ein. In geradegezogenen orthogonalen Bildern dargestellte Objekte können schwierig zu erkennen und/oder zu identifizieren sein, da die meisten Beobachter nicht daran angepasst sind, Objekte, insbesondere erdgebundene Merkmale, von oben zu betrachten. Für einen ungeübten Betrachter weist ein geradegezogenes Abbild eine Zahl von Verzerrungen auf. Straßen, die tatsächlich gerade sind, sehen gekrümmt aus, und Gebäude können sich neigend aussehen. Ferner enthalten geradegezogene Bilder im Wesentlichen keine Information bezüglich der Höhe erdgebundener Merkmale. Die Interpretation und Ausweite orthogonaler und/oder geradegezogener orthogonaler Bilder wird typischerweise von hochtrainierten Auswertern durchgeführt, welche Jahre spezialisierten Trainings und Erfahrung aufzuweisen haben, um Objekte und erdgebundene Merkmale in solchen Bildern zu identifizieren.

[0007] Daher, obwohl orthogonale und geradegezogene Bilder bei der Bildmessung nützlich sind, fehlt ihnen Information über die Höhe von darin abgebildeten Merkmale, und sie benötigen hochtrainierte Auswerter, um genau zu interpretieren, was die Bilder darstellen.

[0008] Schräge Bilder sind Bilder, die mit der allgemein von der Plattform aus, welche die Bildaufnahmevorrichtung trägt, zur Seite oder nach unten gezielten oder ausgerichteten Bildaufnahmevorrichtung aufgenommen worden sind. Schräge Bilder zeigen, im Gegensatz zu orthogonalen Bildern, die Seiten erdgebundener Merkmale, wie beispielsweise von Häusern, Gebäuden und/oder Bergen, als auch die zugehörigen Spitzen. Daher ist das Betrachten eines schrägen Bilds natürlicher und intuitiver als das Betrachten eines orthogonalen oder geradegezogenen Bildes, und sogar flüchtige Betrachter sind in der Lage, erdgebundene Merkmale zu erkennen und zu interpretieren, als auch andere in schrägen Bildern dargestellte Objekte. Jeder Bildpunkt im Vordergrund ei-

nes schrägen Bilds entspricht einer relativ kleinen Fläche der dargestellten Oberfläche oder Objekts (d. h., dass jeder Vordergrund-Bildpunkt einen relativ kleinen Bodenabtastabstand aufweist), wohingegen jeder Bildpunkt im Hintergrund einer relativ großen Fläche der dargestellten Oberfläche oder des dargestellten Objekts entspricht (d. h., dass jeder Hintergrund-Bildpunkt einen relativ großen Bodenabtastabstand aufweist). Schräge Bilder nehmen eine im Allgemeinen trapezförmige Fläche oder Ansicht der Subjektoberfläche oder des Objekts auf, wobei der Vordergrund des Trapezoids einen wesentlich kleineren Grundabtastabstand (d. h., eine höhere Auflösung) aufweist als der Hintergrund des Trapezoids.

[0009] Schräge Bilder werden als überhaupt nicht oder nur wenig nützlich für die Bildmessung angesehen. Der herkömmliche Ansatz des Zwingens der unterschiedlich großen Vordergrund- und Hintergrund-Bildpunkte eines schrägen Abbilds auf eine gleichförmige Größe, um dadurch das Bild auf ein Koordinatensystem zu verformen, verzerrt das schräge Bild dramatisch und macht dadurch die Identifizierung von Objekten und das Aufnehmen von Messungen von darin dargestellten Objekten zu einer arbeitsaufwendigen und ungenauen Aufgabe. Ein Korrigieren von Geländeverschiebungen in einem schrägen Bild durch Verwenden eines Höhenlagenmodells verzerrt die Bilder weiter, wodurch die Schwierigkeit erhöht wird, mit der Messungen durchgeführt werden können, und wodurch die Genauigkeit einer jeden solchen Messung verringert wird.

[0010] Daher sind, obwohl schräge Bilder als wenig oder gar nicht nützlich für die Bildmessung angesehen werden, sie einfach interpretierbar und enthalten Information über die Höhe der darin abgebildeten Merkmale.

[0011] WO 99/18732 A1 offenbart ein System und ein Verfahren zum Aufnehmen, Erdpositionsbestimmen und Messen schräger Bilder, umfassend eine Bildaufnahmevorrichtung, eine Erdpositionsbestimmungsvorrichtung, ein Computersystem und eine Bild- und Datenaufnahme-Software, welche die Bilddaten mit den Erdpositionsbestimmungs-Signaldaten verknüpft.

AUFGABE DER ERFINDUNG

[0012] Was daher auf diesem Gebiet benötigt wird, sind ein Verfahren und eine Vorrichtung zur Bildmessung, welche eine Erdpositionsbestimmung und genaue Messungen in schrägen Bildern ermöglichen.

[0013] Was darüber hinaus auf dem Gebiet benötigt wird, sind ein Verfahren und eine Vorrichtung zur Bildmessung, welche die Messung von Höhen und relativen Höhen von Objekten innerhalb eines Bildes ermöglichen.

[0014] Was ferner auf dem Gebiet benötigt wird, sind ein Verfahren und eine Vorrichtung zur Bildmessung, welche intuitivere und natürlichere Bilder verwenden.

ZUSAMMENFASSUNG DER ERFINDUNG

[0015] Die vorliegende Erfindung stellt ein System nach Anspruch 1 bereit.

KURZE BESCHREIBUNG DER ZEICHNUNGEN

[0016] Die oben erwähnten und andere Merkmale und Vorteile dieser Erfindung, und die Art, sie zu erlangen, werden durch Bezug auf die folgende Beschreibung einer Ausführungsform der Erfindung klar und genauer verstanden, wenn sie zusammen mit den beiliegenden Zeichnungen gelesen wird, worin:

[0017] Fig. 1 eine Ausführungsform einer Plattform oder eines Fahrzeuges darstellt, welches ein erfindungsgemäßes Bildaufnahmesystem trägt und damit aufgenommene beispielhafte orthogonale und schräge Bilder zeigt;

[0018] Fig. 2 eine diagrammatische Sicht des Bildaufnahmesystems aus Fig. 1 ist;

[0019] Fig. 3 ein Blockdiagramm des Bildaufnahmecomputersystems aus Fig. 2 ist;

[0020] Fig. 4 eine Darstellung einer beispielhaften Ausgabedatendatei des Bildaufnahmesystems aus Fig. 1 ist;

[0021] Fig. 5 ein Blockdiagramm einer Ausführungsform eines erfindungsgemäßen Bildanzeige- und Messcomputersystems zum Anzeigen und Aufnehmen von Messungen von und zwischen Objekten ist, welche in den durch das Bildaufnahmesystem aus Fig. 1 aufgenommenen Bildern dargestellt sind;

[0022] Fig. 6 ein beispielhaftes Abbild darstellt, welches auf dem System aus Fig. 5 angezeigt wird, und eine Ausführungsform des erfindungsgemäßen Verfahrens zur Messung von und zwischen in einem solchen Bild dargestellten Objekten darstellt;

[0023] Fig. 7 und Fig. 8 eine Ausführungsform eines erfindungsgemäßen Verfahrens zum Aufnehmen schräger Bilder darstellt;

[0024] Fig. 9 und Fig. 10 eine zweite Ausführungsform eines erfindungsgemäßen Verfahrens zum Aufnehmen schräger Bilder darstellt.

[0025] Entsprechende Bezugszeichen geben entsprechende Teile durch die unterschiedlichen Ansichten hindurch an. Die hierin dargestellten Beispiele stellen eine bevorzugte Ausführungsform der Erfin-

dung dar, und zwar in einer Form, und solche Beispiele sind nicht dazu aufgestellt worden, um den Umfang der Erfindung auf irgendeine Art zu beschränken.

BESCHREIBUNG DER BEVORZUGTEN AUSFÜHRUNGSFORMEN

[0026] Nun bezüglich der Zeichnungen, und insbesondere bezüglich Fig. 1, ist eine Ausführungsform einer Vorrichtung zum Aufnehmen und Erdpositionsbestimmen schräger Bilder nach der vorliegenden Erfindung gezeigt. Die Vorrichtung **10** umfasst eine Plattform oder ein Fahrzeug **20**, welches das Bildaufnahme- und Erdpositionsbestimmungssystem **30** trägt.

[0027] Die Plattform **20**, wie beispielsweise ein Flugzeug, ein Space Shuttle, eine Rakete, ein Satellit oder jedes andere geeignete Fahrzeug, trägt das Bildaufnahmesystem **30** über eine vordefinierte Fläche und auf einer oder mehreren vorbestimmten Höhenlagen über der Oberfläche **31**, wie beispielsweise die Erdoberfläche oder jede andere interessierende Oberfläche. Als solches ist die Plattform **20**, entweder bemannt oder unbemannt, zu einer gesteuerten Bewegung oder Flug in der Lage, und zwar entlang eines vorbestimmten Flugpfads oder -kurses durch beispielsweise die Erdatmosphäre oder den Weltraum. Die Bildaufnahmeplattform **20** umfasst ein System zum Erzeugen und Regeln von Leistung (nicht gezeigt), welches beispielsweise ein oder mehrere Generatoren, Brennstoffzellen, Solarzellen und/oder Batterien zum Antreiben des Bildaufnahmesystems **30** umfasst.

[0028] Das Bildaufnahme- und Erdpositionsbestimmungssystem **30**, wie es am besten in Fig. 2 gezeigt ist, umfasst Bildaufnahmevorrichtungen **32a** und **32b**, einen GPS ("global positioning system")-Empfänger **34**, eine Trägheitsnavigationseinheit ("inertial navigation unit"; INU) **36**, eine Uhr **38**, ein Gyroskop **40**, einen Kompass **42** und einen Höhenmesser **44**, von denen jedes mit einem Bildaufnahmecomputersystem **46** zusammengeschaltet ist.

[0029] Die Bildaufnahmevorrichtungen **32a** und **32b**, wie beispielsweise herkömmliche Kameras, Digitalkameras, digitale Sensoren, ladungsgekoppelte Vorrichtungen ("charge-coupled devices"; CCD) oder jegliche andere geeignete Bildaufnahmevorrichtungen sind in der Lage, Bilder fotografisch oder elektronisch aufzunehmen. Die Bildaufnahmevorrichtungen **32a** und **32b** weisen bekannte oder bestimmbare Eigenschaften auf, einschließlich einer Brennweite, einer Sensorgröße und einem Bildseitenverhältnis, radialen oder anderen Verzerrungstermen, einem Hauptversatzpunkt, einem Bildpunktabstand und eine Anpassung. Die Bildaufnahmevorrichtungen **32a** und **32b** nehmen Bilder auf und geben Bilddatensignale ("image data signals"; IDS) **48a** bzw. **48b** entsprechend den bestimmten aufgenommenen Bildern oder Fotografien aus, welche im Bildaufnahmecomputersystem **46** gespeichert werden, wie es genauer im Folgenden beschrieben wird.

[0030] Wie am besten in Fig. 1 gezeigt, weisen die Bildaufnahmevorrichtungen **32a** und **32b** entsprechende Mittelachsen A_1 und A_2 auf und sind auf der Plattform **20** so befestigt, dass die Achsen A_1 und A_2 jeweils unter einem Neigungswinkel θ relativ zu einer horizontalen Ebene P liegen. Der Neigungswinkel θ ist so gut wie jeder schräge Winkel, beträgt aber vorteilhafter Weise zwischen ca. 20° (zwanzig Grad) und ca. 60° (sechzig Grad) und liegt am meisten bevorzugt zwischen ca. 40° (vierzig Grad) und ca. 50° (fünfzig Grad).

[0031] Der GPS-Empfänger **34** empfängt GPS-Signale **52**, welche von einem oder mehreren GPS-Satelliten **54** ausgesandt werden. Die GPS-Signale **52** ermöglichen auf bekannte Weise die genaue Positionsbestimmung der Plattform **20** relativ zur zu bestimmenden Oberfläche **31**. Der GPS-Empfänger **34** dekodiert GPS-Signale **52** und gibt Positionssignale/-daten **56** aus, welche zumindest teilweise von den GPS-Signalen **52** abhängen und welche die genaue Position der Plattform **20** relativ zur Oberfläche **31** anzeigen. Die Positionssignale/-daten **56**, die zu jedem von den Bildaufnahmevorrichtung **32a** und **32b** aufgenommenen Bildern gehören, werden vom Bildaufnahmecomputersystem **46** empfangen und gespeichert.

[0032] Die INU **36** ist eine herkömmliche Trägheitsnavigationseinheit, welche mit Geschwindigkeitsänderungen der Bildaufnahmevorrichtungen **32a** und **32b** und/oder der Plattform **20** gekoppelt ist und diese erfasst, einschließlich einer Verschiebungs- und einer Drehgeschwindigkeit. Die INU **36** gibt Geschwindigkeitssignale/-daten **58**, die solche Geschwindigkeiten und/oder Änderungen daran anzeigen, an das Bildaufnahmecomputersystem **46** aus, welches die Geschwindigkeitssignale/-daten **58** speichert, welche zu jedem Bild gehören, das durch die Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen wurde, und die durch das Bildaufnahmecomputersystem **46** empfangen und gespeichert werden.

[0033] Die Uhr **38** führt eine genaue Zeitmessung (Validierungszeit) durch, welche verwendet wird, um Ereignisse innerhalb des Bildaufnahme- und Erdpositionsbestimmungssystems **30** zu synchronisieren. Die Uhr **38** stellt ein Zeitdaten/Takt-Signal **62** bereit, welches die genaue Zeit angibt, zu der ein Bild durch die Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen worden ist. Die Zeitdaten **62** werden auch dem Bildaufnahmecomputersystem **46** bereitgestellt und davon gespeichert. Alternativ ist die Uhr **38** im Bildaufnahmecomputersystem **46** integriert, wie bei-

spielsweise als ein Uhrsoftwareprogramm.

[0034] Das Gyroskop **40** ist ein herkömmliches Gyroskop, wie es üblicherweise in Flugzeugen und/oder in kommerziellen Navigationssystemen für Flugzeuge zu finden ist. Das Gyroskop **40** stellt Signale bereit, einschließlich eines Stampfsignals **64**, eines Rollsignals **66** und eines Giersignals **68**, welche entsprechend ein Stampfen, ein Rollen und ein Gieren der Plattform anzeigen. Das Stampfsignal **64**, das Rollsignal **66** und das Giersignal **68** sind jedem Bild zugehörig, welches von den Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen worden ist, und werden vom Bildaufnahmecomputersystem **46** empfangen und gespeichert.

[0035] Der Kompass **42**, wie beispielsweise ein herkömmlicher elektronischer Kompass, gibt die Ausrichtung der Plattform **20** an. Der Kompass **42** gibt Ausrichtungssignale/-daten **72** aus, welche die Ausrichtung der Plattform anzeigen. Das Bildaufnahmecomputersystem **46** empfängt und speichert die Ausrichtungssignale/-daten **72**, welche jedem durch die Bildaufnahmevorrichtungen **32a** und **32b** aufgenommenen Bild entsprechen.

[0036] Der Höhenmesser **44** zeigt die Höhe der Plattform **20** an. Der Höhenmesser **44** gibt Höhenlagensignale/-Daten **74** aus, und das Bildaufnahmecomputersystem **46** empfängt und speichert die Höhenlagensignale/-Daten **74**, die zu jedem Bild gehören, das durch die Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen worden ist.

[0037] Wie am besten in Fig. 3 gezeigt, umfasst das Bildaufnahmecomputersystem **46**, wie beispielsweise ein herkömmlicher Laptop-Personalcomputer, einen Speicher **82**, Eingabevorrichtungen **84a** und **84b**, eine Anzeigevorrichtung **86** und Eingabe/Ausgabe ("input/output"; I/O)-Anschlüsse **88**. Das Bildaufnahmecomputersystem **46** führt eine Bild- und Datenerfassungs-Software **90** aus, welche in dem Speicher **82** gespeichert ist. Der Speicher **82** speichert auch Daten, welche vom Bildaufnahmecomputersystem **46** während seines Betriebs verwendet und/oder berechnet worden sind, und umfasst beispielsweise einen nichtflüchtigen Nur-Lese-Speicher, einen Schreib/Lese-Speicher, einen Plattenspeicher, entfernbare Speicherkarten und/oder andere geeignete Speichervorrichtungen und/oder -medien. Die Eingabevorrichtungen **84a** und **84b**, wie beispielsweise eine Maus, eine Tastatur, ein Joystick oder andere solche Eingabevorrichtungen, ermöglichen die Eingabe von Daten und eine Wechselwirkung eines Nutzers mit der Software, die von dem Bildaufnahmecomputersystem **46** ausgeführt wird. Die Anzeigevorrichtung **86**, wie beispielsweise eine Flüssigkristallanzeige oder eine Kathodenröhre, zeigt dem Benutzer des Bildaufnahmecomputersystems **46** Information an. Eingabe/Ausgabe-Anschlüsse, **88**, wie beispielsweise serielle und parallele Dateneingabe- und -ausgabeanschlüsse, ermöglichen die Eingabe und/oder Ausgabe von Daten zum und vom Bildaufnahmecomputersystem **46**.

[0038] Jedes der oben beschriebenen Datensignale ist mit dem Bildaufnahmecomputersystem **46** verbunden. Insbesondere werden die Bilddatensignale **46**, Erdpositionssignale **56**, Geschwindigkeitssignale **58**, Zeitdatensignal **62**, Stampf-, Roll- und Gier-Signale **64**, **66** bzw. **68**, das Ausrichtungssignal **72** und das Höhenlagensignal **74** über Eingabe/Ausgabe-Anschlüsse **88** vom Bildaufnahmecomputersystem **46** empfangen und innerhalb des zugehörigen Speichers **82** gespeichert.

[0039] Im Gebrauch führt das Bildaufnahmecomputersystem **46** die Bild- und Datenerfassungs-Software **90** aus, welche allgemein das Lesen, das Behandeln und das Speichern der oben beschriebenen Datensignale steuert. Im Besonderen liest die Bild- und Datenerfassungs-Software **90** Datensignale **48a** und **48b** und speichert sie im Speicher **82**. Jedes der Erdpositionssignale **56**, Geschwindigkeitssignale **58**, Zeitdatensignal **62**, Stampf-, Roll- und Gier-Signale **64**, **66** bzw. **68**, das Ausrichtungssignal **72** und das Höhenlagensignal **74**, welche die Zustände darstellen, die zum Zeitpunkt eines Bildes herrschen, das durch die Bildaufnahmevorrichtungen **32a** und **32b** erfasst oder aufgenommen wird, und welche den bestimmten Bilddatensignalen **48a** und **48b** entsprechen, welche die aufgenommenen Bilder darstellen, werden vom Bildaufnahmecomputersystem **46** über Eingabe/Ausgabe-Anschlüsse **88** empfangen. Das Bildaufnahmecomputersystem **46**, welches die Bild- und Datenerfassungssoftware **90** ausführt, gibt ein Bildaufnahmesignal **92** an die Bildaufnahmevorrichtungen **32a** und **32b** aus, um dadurch diese Vorrichtungen zu veranlassen, ein Bild bei vorbestimmten Positionen und/oder zu vorbestimmten Intervallen zu erfassen oder aufzunehmen, welche zumindest teilweise von der Geschwindigkeit der Plattform **20** abhängen.

[0040] Die Bild- und Datenerfassungs-Software **90** dekodiert wie notwendig und speichert und oben genannten Signale im Speicher **82** und ordnet die Datensignale den zugehörigen Bildsignalen **48a** und **48b** zu. Daher sind die Höhe, Ausrichtung in Bezug auf Rollen, Stampfen und Gier und die Position der Bildaufnahmevorrichtungen **32a** und **32b** relativ zur Oberfläche **31**, d. h., der Längengrad und der Breitengrad, für jedes Bild bekannt, welches von den Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen worden ist. Die Plattform **20** wird über einen Bildaufnahmepfad gelenkt oder auf andere Weise geführt, welcher über eine bestimmte Fläche der Oberfläche **31** führt, wie beispielsweise eine vorbestimmte Fläche der Erdoberfläche oder eines anderen Planeten. Vorzugsweise befindet sich der Bildaufnahme-

pfad der Plattform **20** rechtwinklig zu mindestens einer der Grenzen der Fläche von Interesse. Die Anzahl, wie oft die Plattform **20** und/oder die Bildaufnahmevorrichtungen **32a**, **32b** die interessierende Fläche überstreicht, ist zumindest teilweise abhängig von der Größe der Fläche und der in den aufgenommenen Bildern benötigten Detailgenauigkeit. Die bestimmten Details des Bildaufnahmepfads der Plattform **20** werden im Folgenden genauer beschrieben.

[0041] Wenn die Plattform **20** sich über die interessierende Fläche bewegt, wird eine Anzahl schräger Bilder durch die Bildaufnahmevorrichtungen **32a** und **32b** aufgenommen. Wie es vom Fachmann verstanden wird, werden die Bilder durch die Bildaufnahmevorrichtungen **32a** und **32b** zu vorbestimmten Bildaufnahmeintervallen aufgenommen oder erfasst, welche zumindest teilweise von der Geschwindigkeit der Plattform **20** abhängen.

[0042] Bilddatensignale **48a** und **48b**, welche jedem aufgenommenen Bild zugehörig sind, werden vom Bildaufnahmecomputersystem empfangen und in einem Speicher **82** davon gespeichert, und zwar über Eingabe/Ausgabe-Anschlüsse **88**. Auf ähnliche Weise werden die Datensignale (d. h., die Bilddatensignale **48**, die Erdpositionssignale **56**, die Geschwindigkeitssignale **58**, das Zeitdatensignal **62**, die Stampf-, Roll- und Giersignale **64**, **66** bzw. **68**, das Ausrichtungssignal **72** und das Höhenlagensignal **74**), welche jedem aufgenommenen Bild zugehörig sind, von dem Bildaufnahmecomputersystem **46** über Eingabe/Ausgabe-Anschlüsse **88** empfangen und innerhalb eines zugehörigen Speichers **82** gespeichert. Daher wird die Position der Bild-Aufnahmevorrichtungen **32a** und **32b** relativ zur Oberfläche **32** zu dem genauen Zeitpunkt, zu dem jedes Bild aufgenommen wird, im Speicher **82** empfangen und dem zugehörigen aufgenommenen Bild zugeordnet.

[0043] Wie man es am besten in Fig. 1 sieht, entspricht die Position der Bildaufnahmevorrichtungen **32a** und **32b** relativ zur Erde dem Fusspunkt N des orthogonalen Bildes **102**. Daher ist die genaue Erdpositionsbestimmung des Fusspunkts N des orthogonalen Bildes **102** durch Positionssignale **56**, Geschwindigkeitssignale **58**, Zeitdatensignal **62**, Stampf-, Roll- und Gier-Signale **64**, **66** bzw. **68**, das Ausrichtungssignal **72** und das Höhenlagensignal **74** angegeben. Sobald der Fusspunkt N des orthogonalen Bildes **102** bekannt ist, ist die Erdposition jedes anderen Bildpunkts oder Punkts innerhalb des Bildes **102** auf bekannte Weise bestimmbar.

[0044] Wenn die Bildaufnahmevorrichtung **32a** und **32b** schräge Bilder aufnehmen, wie beispielsweise schräge Bilder **104a** und **104b** (Fig. 1), wird die Position der Bildaufnahmevorrichtungen **32a** und **32b** relativ zur Oberfläche **31** ähnlich durch Positionssignale **56**, Geschwindigkeitssignale **58**, das Zeitdatensignal **62**, Stampf-, Roll- und Giersignale **64**, **66** bzw. **68**, das Ausrichtungssignal **72**, das Höhenlagensignal **74** und den bekannten Neigungswinkel θ der Hauptachsen A_1 und A_2 der Bildaufnahmevorrichtungen **32a** bzw. **32b** angegeben.

[0045] Es ist insbesondere anzumerken, dass ein Kalibrierungsprozess es der Bild- und Datenerfassungs-Software **90** ermöglicht, Korrekturfaktoren aufzunehmen und/oder jeden Fehler zu korrigieren, welcher der Bildaufnahmevorrichtung **32** zugehörig ist oder ihr zuzuschreiben ist, wie beispielsweise einen Fehler aufgrund der kalibrierten Brennweite, Sensorgröße, radialen Verzerrung, Hauptpunktversatz und Ausrichtung.

[0046] Die Bild- und Datenerfassungs-Software **90** erzeugt und speichert im Speicher **82** ein oder mehrere Ausgabebild- und -datendateien **120**. Im Besonderen wandelt die Bild- und Datenerfassungs-Software **90** Bilddatensignale **48a**, **48b** und die Orientierungsdatensignale (d. h., die Bilddatensignale **48**, die Erdpositionssignale **56**, die Geschwindigkeitssignale **58**, das Zeitdatensignal **62**, die Stampf-, Roll- und Giersignale **64**, **66** bzw. **68**, das Ausrichtungssignal **72** und das Höhenlagensignal **74**) in computerlesbare Ausgabebild- und -datendateien **120** um. Wie am besten in Fig. 4 gezeigt, umfasst die Ausgabebild- und -datendatei **120** eine Vielzahl von Dateien I_1, I_2, ..., I_n aufgenommener Bilder, welche aufgenommenen schrägen Bildern entsprechen, als auch die Positionsdaten C_{PD1}, C_{PD2}, ..., C_{PDn}, die dazu gehören.

[0047] Die Bilddateien I_1, I_2, ..., I_n der Bild- und Datendatei **120** werden in so gut wie jedem computerlesbaren Bild- oder Grafikdateiformat gespeichert, wie beispielsweise in JPEG-, TIFF-, GIF-, BMP- oder PDF-Datenformaten, und sind mit den Positionsdaten C_{PD1}, C_{PD2}, ..., C_{PDn} kreuzreferenziert, welche ebenfalls als computerlesbare Daten gespeichert werden. Alternativ sind die Positionsdaten C_{PD1}, C_{PD2}, ..., C_{PDn} in den zugehörigen Bilddateien I_1, I_2, ..., I_n in bekannter Weise eingebettet. Die Bilddatendateien **120** werden dann verarbeitet, entweder durch die Bild- und Datenerfassungs-Software **90** oder durch ein Nachverarbeiten, um Fehler zu korrigieren, wie beispielsweise Fehler aufgrund von Abweichungen vom Flugpfad und anderen dem Fachmann bekannten Fehlern. Danach sind die Bilddatendateien **120** fertig zur Verwendung zur Anzeige und zur Durchführung von Messungen von und zwischen den Objekten, die in den aufgenommenen Bildern dargestellt sind, einschließlich von Messungen der Höhen solcher Objekte.

[0048] Nun Bezug nehmend auf Fig. 5 umfasst das Bildanzeige- und -messungscomputersystem **130**, wie beispielsweise ein herkömmlicher Desktop-PC oder ein mobiles Computerendgerät in einem Polizeiwagen, einen Speicher **132**, Eingabevorrichtungen

134a und **134b**, eine Anzeigevorrichtung **136** und eine Netzwerkverbindung **138**. Das Bildaufnahmecomputersystem **130** führt die Bildanzeige- und -auswertesoftware **140** durch, welche im Speicher **132** gespeichert ist. Der Speicher **132** umfasst beispielsweise nichtflüchtigen Nur-Lese-Speicher, Schreib/Lese-Speicher, Plattenspeicher, entfernbare Speicherkarten und/oder andere geeignete Speichervorrichtungen und/oder -medien. Die Eingabevorrichtungen **134a** und **134b**, wie beispielsweise eine Maus, eine Tastatur, ein Joystick oder andere solche Vorrichtungen, ermöglichen die Eingabe von Daten und eine Interaktion eines Nutzers mit einer Bildanzeige- und -auswertesoftware **140**, welche von dem Bildanzeige- und -messungscomputersystem **130** ausgeführt wird. Die Anzeigevorrichtung **136**, wie beispielsweise eine Flüssigkristallanzeige oder eine Kathodenstrahlröhre, zeigt dem Nutzer des Bildanzeige- und -messungscomputersystems **130** Information an. Die Netzwerkverbindung **138** verbindet das Bildanzeige- und Messcomputersystem **130** mit einem Netzwerk (nicht gezeigt), wie beispielsweise einem lokalen Netzwerk ("local-area network"; LAN), einem Fernbereichsnetzwerk ("wide-area network"; WAN), dem Internet und/oder dem World Wide Web.

[0049] Im Gebrauch, und nun bezüglich Fig. 6, greift das Bildanzeige- und -messungscomputersystem **130**, welches die Bildanzeige- und -auswertesoftware **140** ausführt, auf ein oder mehrere Ausgabebild- und -datendateien **120** zu, welche in den Speicher **132** eingelesen worden sind, wie beispielsweise über eine Netzwerkverbindung **138**, eine Diskette, eine entfernbare Speicherkarte oder ein anderes geeignetes Mittel. Ein oder mehrere der aufgenommenen Bilder I_1, I_2, ..., I_n der Ausgabebild- und -datendateien **120** werden danach als angezeigte schräge Bilder **142** unter der Steuerung der Bildanzeige- und -auswertesoftware **140** angezeigt. Zu ungefähr der gleichen Zeit werden ein oder mehrere Datenabschnitte C_{PD1}, C_{PD2}, ..., C_{PDn}, die zu dem angezeigten schrägen Bild **142** gehören, in einen Schreib/Lese-Teil des Speichers **132** eingelesen.

[0050] Es sollte insbesondere bemerkt werden, dass das angezeigte schräge Bild **142** im wesentlichen wie aufgenommen dargestellt wird, d. h., dass das angezeigte Bild **142** nicht verformt oder irgendeinem Koordinatensystem angepasst ist, noch ist das angezeigte Bild **142** geradegezogen. Statt das angezeigte Bild **142** auf ein Koordinatensystem hin zu verformen, um ein Ausmessen von darin dargestellten Objekten zu ermöglichen, bestimmt die Bildanzeige- und -auswertesoftware **140** allgemein die Erdpositionen ausgewählter Bildpunkte nur wie benötigt, oder in Echtzeit, durch Referenzieren von Datenabschnitten C_{PD1}, C_{PD2}, ..., C_{PDn} der Ausgabebild- und Datendateien **120** und Berechnen der Position und/oder Erdposition solcher ausgewählten Bildpunkte unter Verwendung einer oder mehrerer Abbildungsgleichungen, wie es genauer weiter unten beschrieben ist.

[0051] Allgemein führt ein Nutzer des Anzeige- und Mess-Computersystems **130** Messungen von und zwischen Objekten, die in dem angezeigten schrägen Bild **142** dargestellt wird, mittels Auswählen eines von mehreren verfügbaren Messbetriebsarten durch, die in der Bildanzeige- und -auswertesoftware **140** vorgesehen sind. Der Nutzer wählt die gewünschte Messbetriebsart durch Zugreifen auf beispielsweise eine Folge von Pulldownmenüs oder Toolbars M oder durch Tastaturkommandos aus. Die Messbetriebsarten, die von der Bildanzeige- und -auswertesoftware **140** bereitgestellt werden, umfassen beispielsweise eine Abstandsbetriebsart, welche ein Messen des Abstands zwischen zwei oder mehr ausgewählten Punkten ermöglicht, eine Flächenbetriebsart, welche eine Messung der von mehreren ausgewählten und verbundenen Punkten umfassten Fläche ermöglicht, eine Höhenbetriebsart, welches eine Messung der Höhe zwischen zwei oder mehr ausgewählten Punkten ermöglicht, und eine Höhenlagenbetriebsart, welches die Messung der Änderung in der Höhenlage eines ausgewählten Punkts relativ zu einem oder mehreren anderen ausgewählten Punkten ermöglicht.

[0052] Nach Auswählen der gewünschten Messungsbetriebsart, wählt der Nutzer der Bildanzeige- und -auswertesoftware **140** mit einer der Eingabevorrichtungen **134a**, **134b** einen Anfangspunkt oder einen Anfangsbildpunkt **152** und einen Endpunkt oder Endbildpunkt **154** auf dem angezeigten Bild **142** aus, und die Bildanzeige- und -auswertesoftware **140** berechnet automatisch die gesuchte Größe und stellt diese dar, wie beispielsweise den Abstand zwischen dem Anfangsbildpunkt **152** und dem Endbildpunkt **154**.

[0053] Wenn der Nutzer den Anfangspunkt/-bildpunkt **152** auswählt, wird die Erdposition des dazu zugehörigen Punkts auf der Oberfläche **31** durch die Bildanzeige- und -auswertesoftware **140** berechnet, welche ein oder mehrere Abbildungsgleichungen unter Verwendung der Datenabschnitte C_{PD1}, C_{PD2}, ..., C_{PDn} der Ausgabebild- und -datendateien **120** ausführt, welche zu dem bestimmten angezeigten Bild gehören. Der Längengrad und der Breitengrad des Punkts an der Oberfläche **31**, welcher dem Bildpunkt **152** entspricht, werden dann durch die Bildanzeige- und -auswertesoftware **140** auf der Anzeige **136** angezeigt, wie beispielsweise durch Überlagern des Längengrads und des Breitengrads auf das angezeigte Bild **142** benachbart zum ausgewählten Endpunkt/-bildpunkt oder in einem aufklappbaren Anzeigekasten irgendwo auf der Anzeige **136**. Der gleiche Prozessschritt wird vom Nutzer zur Auswahl des Endbildpunkts/-punkts **154** wiederholt, als auch durch die Bildanzeige- und -auswertesoftware **140**

zum Auslesen und Anzeigen der Längengrad- und Breitengradinformation.

[0054] Die Berechnung des Abstands zwischen den Anfangs- und Endpunkten/-pixeln **152** bzw. **154** wird erreicht durch Bestimmen der Erdposition jedes ausgewählten Bildpunkts **152**, **154** in Echtzeit. Die Datenabschnitte C_{PD1}, C_{PD2}, ..., C_{PDn} der Ausgabebild- und -datendatei **120**, welche dem angezeigten Bild entspricht, werden ausgelesen, und die Erdposition des Punkts auf der Oberfläche **31**, welche jedem ausgewählten Bildpunkt entspricht, wird dann bestimmt. Der Unterschied zwischen den Erdpositionen, die zu den ausgewählten Bildpunkten gehören, bestimmt den Abstand zwischen den Bildpunkten.

[0055] Als ein Beispiel, wie die Erdposition eines gegebenen Punkts oder Bildpunkts innerhalb des angezeigten schrägen Bilds **142** bestimmt wird, nehmen wir an, dass das angezeigte Bild **142** dem angezeigten Bild **104a** (Fig. 1) entspricht. Der Nutzer der Bildanzeige- und -auswertesoftware **140** wählt den Bildpunkt **152** aus, welcher aus Gründen der Einfachheit der Mitte C (Fig. 1) des schrägen Bilds **104a** entspricht. Wie in Fig. 1 gezeigt, erstreckt sich die Linie **106** entlang der horizontalen Ebene G von einem Punkt **108** aus, welcher direkt unter der Bildaufnahmevorrichtung **32a** liegt, zur Mitte C der nächsten Grenze oder Kante **108** des schrägen Bilds **104a**. Eine Erweiterung der Hauptachse A_1 schneidet die Mitte C. Ein Winkel ⌀ ist der Winkel, welcher zwischen der Linie **106** der Erweiterung der Hauptachse A_1 gebildet wird. So wird ein Dreieck (nicht mit Bezugszeichen versehen) gebildet, welches Scheitelpunkte an der Bildaufnahmevorrichtung **32a**, dem Punkt **108** und der Mitte C bildet und Seiten **106**, die Verlängerung der Hauptachse A_1 und die vertikale (gestrichelte) Linie **110** zwischen Punkt **108** und der Bildaufnahmevorrichtung **32a** aufweist.

[0056] Die Grundebene G ist eine im Wesentlichen horizontale, ebene oder nicht-schräge Grundebene (und welche typischerweise eine Höhenlage aufweist, welche die durchschnittliche Höhenlage des Geländes widerspiegelt), und dadurch umfasst das oben beschriebene Dreieck einen rechten Winkel zwischen der Seite/Linie **110** und der Seite/Linie **106**. Da der Winkel ⌀ und die Höhenlage der Bildaufnahmevorrichtung **32** (d. h., die Länge der Seite **110**) bekannt sind, werden die Hypotenuse (d. h., die Länge der Verlängerung der Hauptachse A_1) und die übrige andere Seite des rechten Dreiecks durch einfache Geometrie berechnet. Da ferner die genaue Position der Bildaufnahmevorrichtung **32a** zu der Zeit bekannt ist, zu der das zum angezeigten Bild **142** entsprechende Bild aufgenommen wurde, sind auch der Breitengrad und der Längengrad von Punkt **108** bekannt. Die Kenntnis der Länge der Seite **106**, welche wie oben beschrieben berechnet wurde, ermöglicht die genaue Erdpositionsbestimmung von Bildpunkt **154**, welches der Mitte C des schrägen Bildes **104a** entspricht, durch die Bildanzeige- und -auswertesoftware **140**. Sobald die Erdposition des Punktes, welcher dem Bildpunkt **154** entspricht, bekannt ist, ist die Erdposition jedes anderen Bildpunkts im angezeigten schrägen Bild **142** unter Verwendung der bekannten Kameraeigenschaften bestimmbar, wie beispielsweise der Brennweite, der Sensorgröße und dem Bildseitenverhältnis, radialen und anderen Verzerrungstermen usw.

[0057] Der Abstand zwischen zwei und mehr Punkten, welche zwei oder mehr ausgewählten Bildpunkten innerhalb des angezeigten Bilds **142** entsprechen, wird von der Bildanzeige- und -auswertesoftware **140** durch Bestimmen des Unterschieds zwischen den Erdpositionen der ausgewählten Bildpunkte unter Verwendung bekannter Algorithmen berechnet, wie beispielsweise durch die Gauss'sche Formel und/oder die Fluchtpunktsformel, und zwar abhängig von der ausgewählten Messbetriebsart. Die Messung von Objekten, die in dem angezeigten Bild **142** dargestellt sind oder dort auftreten, wird mittels eines im Wesentlichen ähnlichen Ablaufs zu dem oben beschriebenen Ablauf zum Ausmessen von Abständen zwischen ausgewählten Bildpunkten durchgeführt. Beispielsweise werden die Längen, Breiten und Höhen von Objekten, wie beispielsweise von Gebäuden, Flüssen, Straßen und so gut wie jeder anderen geografischen oder menschengemachten Struktur, welche auf dem angezeigten Bild **142** auftauchen, durch Auswählen der geeigneten/gewünschten Messbetriebsart und durch Auswählen von Anfangs- und Endbildpunkten ausgemessen.

[0058] Es sollte insbesondere angemerkt werden, dass in der Abstandsmessungsbetriebsart der Bildanzeige- und -auswertesoftware **140** der Abstand zwischen den Anfangs- und Endpunkten/Bildpunkten **152** bzw. **154** entlang so gut wie jeden Pfads bestimmbar ist, wie beispielsweise entlang eines "geradlinigen" Pfads P1 oder eines Pfads P2, welcher die Auswahl von Zwischen-Punkten/Bildpunkten und einem oder mehreren "geradlinigen" Abschnitten, die darin verbunden sind, umfasst.

[0059] Es sollte insbesondere angemerkt werden, dass die Abstandsmessungsbetriebsart der Bildanzeige- und -auswertesoftware **140** den Abstand zwischen ausgewählten Bildpunkten gemäß dem "Fußgänger" ("walk the earth")-Verfahren bestimmt wird. Das "Fußgänger"-Verfahren erzeugt eine Folge zusammenhängender Linienabschnitte, welche gemeinsam durch die Pfade P1 und P2 dargestellt werden, die sich zwischen den ausgewählten Bildpunkten/Punkten erstrecken und welche auf den ebenen Flächen einer Folge zusammenhängender Facetten liegen, oder an diese angepasst sind, welche eine schachbrettartige bzw. mosaikartige Grundebene definieren. Die mosaikartige Grundebene folgt, wie ge-

nauer später beschrieben wird, dem Gelände der Oberfläche **31** eng oder erschafft es neu, und dadurch folgen auch die Pfade P1 und P2 dem Gelände der Oberfläche **31** eng. Durch Ausmessen des Abstands entlang des durch die mosaikartige Grundebene simulierten Geländes stellt das "Fußgänger"-Verfahren eine genauere und nützlichere Abstandsmessung zwischen ausgewählten Punkten bereit als der herkömmliche Ansatz, welcher das Bild auf eine flache Erdoberfläche oder auf ein Ebenensystem durchschnittlicher Höhenlage verformt und den Abstand zwischen ausgewählten Punkten entlang der flachen Erde oder Ebene ausmisst und im Wesentlichen Geländeschwankungen zwischen den Punkten ignoriert.

[0060] Beispielsweise kann ein Bauunternehmer, welcher sich darauf vorbereitet, für einen Vertrag zum Bahnen einer Fahrbahn über unebenes oder hügliges Gelände zu bieten, die ungefähre Größe oder Fläche der damit verbundenen Fahrbahn unter Verwendung der Bildanzeige- und -auswertesoftware **140** und des damit bereitgestellten "Fußgänger"-Ausmessverfahrens bestimmen. Der Bauunternehmer kann die ungefähre Größe oder Fläche der Fahrbahn von seinem oder ihrem Büro aus erlangen, ohne einen Landvermessungstrupp zum Bauplatz zu schicken, um die notwendigen Messungen zu erhalten.

[0061] Im Unterschied zu dem durch die vorliegende Erfindung bereitgestellten "Fußgänger"-Verfahren, beinhalten die "flache Erde"- oder Durchschnittshöhenabstands-Berechnungsansätze inhärente Ungenauigkeiten, wenn sie Abstände zwischen Punkten und/oder Objekten ausmessen, welche sich auf unebenem Gelände befinden, oder wenn sie die Größen und/oder Höhen der ähnlich angeordneten Objekte ausmessen. Sogar eine geringe Steigung oder Neigung in der Oberfläche, die aufgenommen wird, führt zu einem Unterschied in der Höhenlage des Fusspunkts relativ zu so gut wie jedem anderen interessierenden Punkt darauf. Daher mag, wieder in Bezug auf Fig. 1, das durch die Linie **106**, die Verlängerung der Hauptachse A_1 und die vertikale (gestrichelte) Linie **110** zwischen Punkt **108** und der Bildaufnahmevorrichtung **32a** gebildete Dreieck kein richtiges Dreieck sein. Falls dies der Fall ist, würden jegliche geometrische Berechnungen, welche annehmen, dass das Dreieck ein richtiges Dreieck ist, Fehler enthalten, und solche Berechnungen würden aufgrund sogar eines leichten Gradienten oder Steigung zwischen den interessierenden Punkten zu Abschätzungen verringert werden.

[0062] Falls sich beispielsweise die Oberfläche **31** zwischen dem Fusspunkt N und der Mitte C an der nahen oder unteren Kante **108** des schrägen Bilds **104** nach oben neigt, schneidet die zweite Linie **110** die Oberfläche **31** dann vor dem Punkt, an welchem eine solche Kreuzung auf einer ebenen oder sich nicht neigenden Oberfläche **31** auftreten würde. Falls die Mitte C 15 Fuß höher als der Fusspunkt N ist und einen Neigungswinkel θ gleich 40° (vierzig Grad) aufweist, würde die berechnete Position der Mitte C um ungefähr 17,8 Fuß versetzt sein ohne Korrektur der Änderung in der Höhenlage zwischen den Punkten.

[0063] Wie allgemein oben diskutiert, referenziert, um zumindest teilweise Änderungen in der Höhenlage und die sich ergebenden Ungenauigkeiten in der Ausmessung von und zwischen Objekten innerhalb des Bildes **142** zu kompensieren, die Bildanzeige- und -auswertesoftware **140**, wie notwendig, Punkte innerhalb des angezeigten Bilds **142** und auf der Oberfläche **31** auf eine vorberechnete mosaikförmige oder aus Facetten aufgebaute Grundebene, welche in Fig. 6 allgemein mit **160** bezeichnet ist. Die mosaikartige Grundebene **160** umfasst eine Vielzahl von einzelnen Facetten **162a**, **162b**, **162c** usw., wobei jede von diesen miteinander verbunden sind und durch vier Scheitelpunkte (nicht mit Bezugszeichen versehen, aber als Punkte eingezeichnet) mit entsprechenden Höhenlagen definiert sind. Benachbarte Paare von Facetten **162a**, **162b**, **162c** usw. teilen sich zwei Scheitelpunkte. Jede Facette **162a**, **162b**, **162c** usw. weist eine entsprechende Neigung und Steigung auf. Die mosaikartige Grundebene **160** wird auf der Grundlage verschiedener Daten und Ressourcen erzeugt, wie beispielsweise aus topografischen Karten und/oder digitalen Rastergrafiken, Landvermessungsdaten und verschiedenen anderen Quellen.

[0064] Allgemein wird die Erdposition eines interessierenden Punktes auf dem angezeigten Bild **142** berechnet durch Bestimmen, welche der Facetten **162a**, **162b**, **162** usw. zu diesem Punkt von Interesse gehört. Daher wird die Position des interessierenden Punktes auf der Grundlage der Eigenschaften, d. h., der Höhenlage, der Neigung und der Steigung der Facetten **162a**, **162b**, **162c** usw., statt auf der Grundlage einer flachen Grundebene oder einer solchen mit einer gemittelten Höhenlage berechnet. Ein Fehler wird nur in soweit eingeführt, als dass die Topografie der Oberfläche **31** und die Position des interessierenden Punktes darauf sich von der ebenen Oberfläche der Facette **162a**, **162b**, **162c** usw. unterscheidet, innerhalb welcher der interessierende Punkt liegt. Dieser Fehler ist durch eine bilineare Interpolation der Höhenlage des interessierenden Punktes mit einer bestimmten Facette **162a**, **162b**, **162c** usw. und Verwenden dieser interpolierten Höhenlage bei der Positionsberechnung, welche durch die Bildanzeige- und -auswertesoftware **140** durchgeführt wird, verringerbar.

[0065] Um die mosaikartige Grundebene **160** zu nutzen, verwendet die Bildanzeige- und -auswertesoftware **140** einen modifizierten Sehstrahl-Verfolgungsalgorithmus, um die Kreuzung des abgebilde-

ten Strahls von der Bildaufnahmevorrichtung **32a** oder **32b** in Richtung der Oberfläche **31** und der mosaikartigen Grundebene **160** zu finden. Der Algorithmus bestimmt nicht nur, welche der Facetten **162a**, **162b**, **162c** usw. von dem Sehstrahl geschnitten bzw. gekreuzt wird, sondern auch, wo innerhalb der Facette die Überschneidung auftritt. Durch Verwendung der bilinearen Interpolation kann eine angemessen genaue Bodenposition bestimmt werden. Für die umgekehrte Abbildung wird die mosaikartige Grundebene **160** verwendet, um den Grundhöhenlagenwert für die Eingabegrundposition zu finden, und zwar ebenfalls unter Verwendung einer bilinearen Interpolation. Die Höhenlage und die Position werden dann dazu verwendet, rückwärts durch ein Modell der Bildaufnahmevorrichtung **32a** oder **32b** abzubilden, um zu bestimmen, welcher der Bildpunkte innerhalb des angezeigten Bildes **142** mit der gegebenen Position übereinstimmt.

[0066] Im Besonderen, und als ein Beispiel, führt die Bildanzeige- und -auswertesoftware **140** die Erdpositionsbestimmung von Punkt **164** durch, oder berechnet sie, durch Überlagern und/oder Anpassen der mosaikartigen Grundebene **160** an mindestens einen Abschnitt **166**, wie beispielsweise einen Hügel, der Oberfläche **31**. Es sollte angemerkt werden, dass nur ein kleiner Bereich der mosaikartigen Grundebene **160** und der zugehörigen Facetten **162a**, **162b**, **162c** usw. entlang des Profils von Bereich **166** der Oberfläche **31** gezeigt ist. Wie oben diskutiert, wird jede der Facetten **162a**, **162b**, **162c** usw. durch vier Scheitelpunkte definiert, von denen jeder eine entsprechende Höhenlage aufweist und jeder der Facetten entsprechende Neigungen und Steigungen aufweist. Die bestimmte Position von Punkt **164** auf der Ebene/Oberfläche der Facette **162a**, **162b**, **162c** usw., innerhalb welcher Punkt **164** (oder seine Abbildung) liegt, wird wie oben beschrieben bestimmt.

[0067] Die mosaikartige Grundebene **160** wird vorzugsweise außerhalb des Betriebs des Bildanzeige- und -mess-Computersystems **130** und der Bildanzeige- und -auswertesoftware **140** erzeugt. Stattdessen nimmt die mosaikförmige Grundebene **160** die Form einer relativ einfachen Datentabelle oder Nachschlagetabelle **168** an, welche im Speicher **132** des Bildanzeige- und -messungscomputersystems **130** liegt, oder von diesem aus zugreifbar ist. Die Rechenkapazitäten, die benötigt werden, um die Positionen all der Scheitelpunkte der vielen Facetten einer typischen Grundebene zu berechnen, müssen nicht notwendiger Weise im Bildanzeige- und -messungscomputersystem **130** untergebracht sein. Daher ist das Bildanzeige- und -messungscomputersystem **130** kompatibel zur Verwendung mit und ausführbar durch einem herkömmlichen Personal Computer, ohne dass zusätzliche Rechenkapazitäten benötigt werden.

[0068] Das Berechnen der mosaikartigen Grundebene **160** außerhalb des Bildanzeige- und -messungscomputersystems **130** ermöglicht es, dass so gut wie jeden Detailgrad in die mosaikartige Grundebene **160** einzubeziehen, d. h., die Größe und/oder Fläche, welche von jeder der Facetten **162a**, **162b**, **162c** usw. abgedeckt wird, oder diesen entspricht, so groß oder so klein wie gewünscht sein kann, und zwar ohne die Berechnungszeit wesentlich zu erhöhen, den Betrieb davon zu verlangsamen oder die Ressourcen wesentlich zu erhöhen, welche von dem Bildanzeige- und -messungscomputersystem **130** und/oder der Bildanzeige- und -auswertesoftware **140** benötigt werden. Das Anzeige- und -messungscomputersystem **130** kann daher ein relativ grundsätzliches und unkompliziertes Computersystem sein.

[0069] Die Größe der Facetten **162a**, **162b**, **162c** usw. ist gleichförmig in ihrer Größe über ein bestimmtes angezeigtes Bild **142**. Falls beispielsweise das angezeigte Bild **142** einer Fläche entspricht, die im Vordergrund ungefähr 750 Fuß breit mal ungefähr 900 Fuß tief ist, kann das Bild in Facetten aufgebrochen werden, welche ungefähr 50 Quadratfuß messen, wodurch sich ca. 15 Facetten in der Breite und 18 Facetten in der Tiefe ergeben. Alternativ kann die Größe der Facetten **162a**, **162b**, **162c** usw, in Bezug auf die darin enthaltene Zahl von Bildpunkten gleichförmig sein, d. h., dass jede Facette die gleiche Zahl von Bildpunkten in der Breite und die gleiche Zahl von Bildpunkten in der Tiefe aufweist. Die Facetten im Vordergrund des angezeigten Bildes **142**, wo die Bildpunktdichte am größten ist, würden daher ausdehnungsmäßig kleiner sein als die Facetten im Hintergrund des angezeigten Bildes **142**, wo die Bildpunktdichte am niedrigsten ist. Da es wünschenswert ist, die meisten Messungen im Vordergrund eines angezeigten Bilds durchzuführen, wo die Bildpunktdichte am größten ist, weist ein Erzeugen von Facetten, welche in Bezug auf die Zahl der enthaltenen Bildpunkte gleichförmig sind, den Vorteil auf, genauere Messungen im Vordergrund des angezeigten Bilds **142** in Bezug auf die Facetten zu ermöglichen, welche ausdehnungsmäßig gleichförmig sind.

[0070] Ein weiterer Vorteil des Verwendens von Bildpunkten als einer Grundlage zum Definieren der Abmessungen der Facetten **162a**, **162b**, **162c** usw. ist es, dass die Positionsberechnung (Bildpunktposition zu Boden- bzw. Grundposition) relativ einfach ist. Ein Benutzer betreibt das Bildanzeige- und -messungscomputersystem **130**, um einen Bildpunkt innerhalb einer gegebenen Facette auszuwählen, und die Bildanzeige- und -auswertesoftware **140** schlägt die Daten für die dem ausgewählten Bildpunkt zugehörige Facette nach, die Höhenlage des ausgewählten Bildpunkts wird wie oben beschrieben berechnet, und diese Höhenlage wird bei der Positionsberechnung verwendet.

[0071] Allgemein teilt das erfindungsgemäße Verfahren zum Aufnehmen schräger Bilder eine interessierende Fläche, wie beispielsweise einen Landkreis, in Sektoren von allgemein gleichförmiger Größe auf, wie beispielsweise in Sektoren, welche annähernd eine Fläche von 1 Quadratmeile aufweisen. Dies wird getan, um die Erzeugung eines Flugplans zu vereinfachen, um schräge Bilder aufzunehmen, welche jeden Zentimeter der interessierenden Fläche abdecken, und um die Abschnitte und/oder deren Bilder zur einfachen Referenzierung, Speicherung und Wiedergewinnung zu organisieren und zu benamen (ein Ablauf, der im Stand der Technik als "Sektorisierung" bekannt ist). Weil die Kanten jeder geografischen interessierenden Fläche, wie beispielsweise eines Landkreises, selten auf gerade Quadratmeilengrenzen fallen, stellt das Verfahren zum Aufnehmen schräger Bilder nach der vorliegenden Erfindung mehr Abschnitte bzw. Sektoren bereit als Quadratmeilen in der interessierenden Fläche vorhanden sind – wie viele mehr, hängt zum großen Teil von der Länge der Landkreisgrenzen ab, als auch davon, wie gerade oder zackig sie sind. Typischerweise kann man einen zusätzlichen Abschnitt für alle zwei bis drei Meilen an Grenze erwarten. Falls ein solcher Landkreis oder eine andere interessierende Fläche grob 20 Meilen × 35 Meilen, oder 700 Quadratmeilen, groß ist, wird die Fläche in annähernd 740 bis 780 Sektoren aufgeteilt.

[0072] Das erfindungsgemäße Verfahren zum Aufnehmen schräger Bilder nimmt allgemein die schrägen Bilder von mindestens zwei Kompassrichtungen bzw. Marschzahlen aus auf und stellt eine volle Abdeckung der interessierenden Fläche aus zumindest diesen zwei Marschzahlen zur Verfügung. Nun Bezug nehmend auf die Fig. 7 und Fig. 8 wird eine erste Ausführungsform eines erfindungsgemäßen Verfahrens zum Aufnehmen schräger Bilder gezeigt. Aus Gründen der Klarheit basieren die Fig. 7 und Fig. 8 auf einem System, welches nur eine Bildaufnahmevorrichtung aufweist. Es ist jedoch so zu verstehen, dass zwei oder mehr Bildaufnahmevorrichtungen verwendet werden können.

[0073] Die Bildaufnahmevorrichtung nimmt ein oder mehrere schräge Bilder während jedes Überflugs bzw. Überfahrens von Fläche **200** auf. Die Bildaufnahmevorrichtung ist, wie oben diskutiert, unter einem Winkel auf die Fläche **200** ausgerichtet, um zugehörige schräge Bilder aufzunehmen. Fläche **200** wird durch die bildtragende Vorrichtung und/oder die Plattform in einem Vorwärts-Rückwärts-Muster durchquert, ähnlich dazu, wie ein Rasen gemäht wird, um eine doppelte Abdeckung der Fläche **200** sicherzustellen.

[0074] Im Besonderen wird die Fläche **200** dadurch überquert, dass die bildtragende Vorrichtung **32** und/oder Plattform **20** einen ersten Pfad **202** folgen, um dadurch schräge Bilder von Bereichen **202a**, **202b** und **202c** der Fläche **200** aufzunehmen. Die Fläche **200** wird dann dadurch überquert, dass die bildtragende Vorrichtung **32** und/oder Plattform **20** einem zweiten Pfad **204** folgt, welcher parallel zum und beabstandet vom, und in einer entgegengesetzten Richtung zu, d. h., 180° (einhundertundachtzig Grad) zum ersten Pfad **202** liegt, um dadurch schräge Bilder der Bereiche **204a**, **204b**, **204c** der Fläche **200** aufzunehmen. Durch Vergleichen der Fig. 7 und Fig. 8 kann man erkennen, dass ein Bereich **207** (Fig. 8) von Fläche **200** durch die Bilder **202a**–c abdeckt wird, welche aus einer ersten Richtung oder Perspektive aus aufgenommen worden sind, als auch durch Bilder **204a**–c, welche aus einer zweiten Richtung oder Perspektive aus aufgenommen worden sind. Als solches wird der Mittelteil der Fläche **200** 100%ig (einhundertprozentig) doppelt abgedeckt. Das oben beschriebene Muster des Überquerens bzw. Überfahrens der Fläche **200** entlang entgegengesetzter Pfade, welche parallel zu den Pfaden **202** und **204** liegen, wird wiederholt, bis die gesamte Fläche **200** vollständig von mindestens einem schrägen Bild abgedeckt ist, welches von den Pfaden, die zueinander parallel und voneinander beabstandet liegen, aus aufgenommen worden ist, wie durch die Größe der Fläche **200** bestimmt, als auch aus der gleichen Richtung wie die Pfade **202** und **204**, um dadurch eine 100%ige doppelte Abdeckungsfläche **200** aus diesen Perspektiven/Richtungen zu erhalten.

[0075] Falls gewünscht, und für eine verbesserte Detailgenauigkeit, wird die Fläche **200** durch zwei zusätzliche entgegengesetzte und parallele dritte und vierte Pfade **206** bzw. **208** abgedeckt, welche senkrecht zu den Pfaden **202** und **204** laufen, wie in den Fig. 9 und Fig. 10 gezeigt. Die Fläche **200** wird daher durch die bildtragende Vorrichtung **32** und/oder Plattform **20** einem dritten Pfad **206** folgend überquert, um schräge Bilder der Bereiche **206a**, **206b** und **206c** der Fläche **200** aufzunehmen, und wird dann entlang eines vierten Pfads **208** überquert, welcher parallel, beabstandet und entgegengesetzt dem dritten Pfad **206** ist, um schräge Bilder der Bereiche **208a**, **208b** und **208c** der Fläche **200** aufzunehmen. Dieses Muster des Durchquerens bzw. Überfliegens der Fläche **200** entlang entgegengesetzter Pfade, welche parallel zu den Pfaden **206** und **208** liegen, wird auf ähnliche Weise wiederholt, bis die gesamte Fläche **200** vollständig von mindestens einem schrägen Bild abgedeckt ist, welches von den Pfaden aufgenommen worden ist, die parallel und zueinander beabstandet liegen, wie durch die Größe der Fläche **200** vorgegeben, und in der gleichen Richtung liegen wie die Pfade **206** und **208**, um dadurch die Fläche **200** aus diesen Richtungen/Perspektiven 100%ig doppelt abzudecken.

[0076] Wie oben beschrieben, überquert die bildtragende Vorrichtung **32** und/oder Plattform **20** die Flä-

che **200** entlang eines vorbestimmten Pfads. Jedoch sollte es klar sein, dass die bildtragende Vorrichtung und/oder Plattform **20** nicht notwendigerweise die Fläche **200** direkt überfliegt oder durchquert, sondern stattdessen eine benachbarte Fläche überfliegen oder durchqueren kann, welche der Fläche **200** benachbart ist, oder sogar etwas davon entfernt ist, um sicherzustellen, dass der Bereich der Fläche **200**, welcher aufgenommen wird, in das Bildaufnahmefeld der Bildaufnahmevorrichtung fällt. Der Pfad **202**, wie in Fig. 7 gezeigt, ist ein solcher Pfad, als dass er nicht direkt die Fläche **200** überfliegt, und dennoch schräge Bilder davon aufnimmt.

[0077] Die vorliegende Erfindung ist in der Lage, Bilder bei verschiedenen Auflösungspegeln oder Grundabtastungsabständen aufzunehmen. Eine erste Detailebene, im Folgenden als eine Gebietsebene bezeichnet, weist einen Grundabtastabstand von beispielsweise ca. 2 Fuß pro Bildpunkt auf. Für orthogonale Gebietsebenenbilder bleibt der Grundabtastabstand im Wesentlichen über das Bild konstant. Orthogonale Gebietsebenenaufnahmen werden mit einem ausreichenden Überlapp aufgenommen, um eine Stereopaarabdeckung bereitzustellen. Für schräge Gebietsebenenbilder variiert der Grundabtastabstand von beispielsweise ungefähr 1 Fuß pro Bildpunkt im Vordergrund des Bildes bis ungefähr 2 Fuß pro Bildpunkt im Mittelbereich des Bildes und bis ungefähr 4 Fuß pro Bildpunkt im Hintergrund des Bildes. Schräge Gebietsebenenbilder werden mit ausreichendem Überlapp aufgenommen, so dass jede interessierende Fläche typischerweise von mindestens zwei schrägen Bildern aus jeder Kompassrichtung aufgenommen wird. Ungefähr 10 schräge Gebietsebenenbilder werden pro Sektor aufgenommen.

[0078] Eine zweite Detailebene, im Folgenden als Nachbarschaftsebene bezeichnet, ist erheblich detaillierter als die Gebietsebenenbilder. Die Nachbarschaftsebenenbilder weisen einen Grundabtastabstand von beispielsweise ungefähr 6 inch pro Bildpunkt auf. Für orthogonale Nachbarschaftsebenenbilder bleibt der Grundabtastabstand im Wesentlichen konstant. Schräge Nachbarschaftsebenenbilder weisen einen Grundabtastabstand von beispielsweise ungefähr 4 inch pro Bildpunkt im Vordergrund des Bildes bis zu ungefähr 6 inch pro Bildpunkt im Mittenbereich des Bildes und bis zu ungefähr 10 inch pro Bildpunkt im Hintergrund des Bildes auf. Schräge Nachbarschaftsebenenbilder werden mit ausreichend Überlapp aufgenommen, so dass jeder interessierende Bereich typischerweise von mindestens zwei schrägen Bildern aus jeder Marschzahl aufgenommen wird, und so, das entgegengesetzte Marschzahlen eine 100%ige Überlappung miteinander vorsehen. Ungefähr einhundert (100) schräge Flächenaufnahmen werden pro Sektor aufgenommen.

[0079] Es sollte insbesondere angemerkt werden, dass ein Aufnehmen schräger Bilder auf Gemeinde- und/oder Nachbarschaftsebene aus allen vier Kompassrichtungen sicherstellt, dass jeder Punkt im Bild im Vordergrund oder unteren Bereich mindestens eines der aufgenommenen schrägen Bilder auftaucht, wo der Grundabtastabstand am niedrigsten und die Bilddetailschärfe am größten ist.

[0080] In der gezeigten Ausführungsform umfasst das Bildaufnahme- und Erdpositionsbestimmungssystem **30** ein Gyroskop, einen Kompass und einen Höhenmesser. Es sollte jedoch klar sein, dass das erfindungsgemäße Bildaufnahme- und Erdpositionsbestimmungssystem alternativ eingerichtet sein kann, wie beispielsweise, um eine Höhe, ein Stampfen, Rollen und Gieren abzuleiten und/oder zu berechnen, als auch eine Kompassflugrichtung aus den GPS- und INU-Signalen/Daten, um ein oder mehrere von dem Gyroskop, Kompass oder Höhenmesser überflüssig zu machen.

[0081] In der gezeigten Ausführungsform liegen die Bildaufnahmevorrichtungen auf einem gleichen Neigungswinkel relativ zu einer horizontalen Ebene. Es sollte jedoch klar sein, dass die Neigungswinkel der Bildaufnahmevorrichtungen nicht gleich zu sein brauchen.

[0082] In der gezeigten Ausführungsform führt das Bildaufnahmecomputersystem die Bild- und Datenerfassungs-Software aus, welche ein gemeinsames oder ein einzelnes Bildaufnahmesignal an die Bildaufnahmevorrichtungen ausgibt, um dadurch zu bewirken, dass diese Vorrichtungen ein Bild erfassen oder aufnehmen. Es sollte jedoch klar sein, dass die vorliegende Erfindung alternativ so eingerichtet werden kann, dass sie die Bildaufnahmevorrichtungen separat dazu veranlasst, Bilder zu unterschiedlichen Zeitpunkten und/oder mit unterschiedlichen Zeitdauern aufzunehmen.

[0083] In der gezeigten Ausführungsform nimmt das erfindungsgemäße Verfahren schräge Bilder auf, um eine doppelte Abdeckung einer interessierenden Fläche von Pfaden/Perspektiven aus bereitzustellen, welche im Wesentlichen zueinander entgegengesetzt liegen, d. h., 180° (einhundertundachtzig Grad) relativ zueinander liegen. Jedoch sollte es klar sein, dass das erfindungsgemäße Verfahren alternativ so ausgestaltet werden kann, dass es eine doppelte Abdeckung von Pfaden/Perspektiven aus bereitstellen kann, welche allgemein und/oder im Wesentlichen senkrecht relativ zueinander liegen.

[0084] Während die vorliegende Erfindung als mit einer bevorzugten Ausführungsform versehen beschrieben worden ist, kann die Erfindung ferner innerhalb des Umfangs der Ansprüche modifiziert werden. Diese Offenbarung ist daher dazu gedacht, jeg-

liche Äquivalente bezüglich der hierin offenbarten Strukturen und Elemente zu umfassen. Ferner ist diese Offenbarung dazu gedacht, jegliche Änderungen, Verwendungen oder Anpassungen der vorliegenden Erfindung zu umfassen, welche die hierin offenbarten allgemeinen Grundlagen verwenden. Darüber hinaus ist diese Offenbarung dazu gedacht, jegliche Abweichungen vom offenbarten Gegenstand zu umfassen, welche innerhalb der bekannten oder üblichen Praxis des Standes der Technik liegen und welche in den Bereich der angehängten Ansprüche fallen.

Patentansprüche

1. Computerisiertes System zum Darstellen, Erdpositionsbestimmen und Durchführen von Messungen auf der Grundlage aufgenommener schräger Bilder, umfassend:
ein Computersystem (**130**) mit einem Speicher (**132**);
eine Bild- und Datendatei (**120**), auf die durch das System (**130**) zugegriffen werden kann, und die eine Vielzahl von Bilddateien umfasst, die einer Vielzahl aufgenommener schräger Bilder entsprechen, wobei die Bild- und Datendatei (**120**) weiterhin Positionsdaten umfasst, die zu der Vielzahl von Bilddateien gehören; und
eine Bildanzeige- und -analyse-Software (**140**), die von dem System (**130**) zum Lesen der Bild- und Datendatei (**120**) und zum Anzeigen mindestens eines Teils der aufgenommenen schrägen Bilder als ein angezeigtes schräges Bild ausgeführt wird, wobei die Bildanzeige- und -analyse-Software (**140**) die Erdpositionen von zwei oder mehr ausgewählten Punkten zumindest teilweise auf der Grundlage der Positionsdaten berechnet, wobei die Bildanzeige- und -analyse-Software (**140**) einen Abstand zwischen allen zwei oder mehr ausgewählten Punkten innerhalb des angezeigten schrägen Bildes berechnet;
gekennzeichnet durch
eine Grundebenendatendatei eine mosaikartige Grundebene (**160**) darstellt, wobei die Grundebenendatendatei der Bildanzeige- und -analyse-Software (**140**) Daten bereitstellt, wobei die Grundebenendatendatei eine mosaikartige Grundebene darstellt, welche zumindest einen Teil des innerhalb des aufgenommenen schrägen Bildes dargestellten Geländes nah annähert, wobei die mosaikartige Grundebene weiterhin eine Vielzahl zusammenhängender Bilder umfasst, wobei die mosaikartige Grundebene weiterhin eine Vielzahl zusammenhängender Facetten (**162a**, **162b**, **162c**, ...) umfasst, wobei jede der Vielzahl von Facetten einen entsprechende Abstand und Steigung aufweist, wobei die Grundebenendatendatei eine Vielzahl von Eckpunkten umfasst, wobei jeder der Vielzahl von Eckpunkten entsprechende Höhelagen aufweist und Ecken der Vielzahl der zusammenhängenden Facetten (**162a**, **162b**, **162c**, ...) definiert, wobei jede der zusammenhängenden Facetten sich zwei aus der Vielzahl der Facetten teilt; und
die Bildanzeige- und -analyse-Software (**140**), die identifiziert, welche der Vielzahl der Facetten zu einem ausgewählten Punkt auf dem angezeigten schrägen Bild gehört, und die eine Höhe des ausgewählten Punkts abhängig zumindest teilweise von der Höhenlage der Eckpunkte derjenigen Facette berechnet, die zu dem ausgewählten Punkt gehört, wobei die Bildanzeige- und -analyse-Software (**140**) die berechnete Höhenlage zum Berechnen des Abstandes zwischen dem ausgewählten Punkt und einem oder mehreren weiteren ausgewählten Punkten verwendet.

2. System nach Anspruch 1, wobei die Bildanzeige- und -analyse-Software (**140**) die Erdpositionen nur bei Bedarf berechnet.

3. System nach Anspruch 1 oder 2, wobei die Bildanzeige- und -analyse-Software (**140**) eine Höhe eines innerhalb des angezeigten schrägen Bildes vorhandenen Objekts berechnet, und zwar durch Berechnen des Abstandes zwischen zwei oder mehr ausgewählten Punkten.

4. System nach einem der Ansprüche 1 bis 3, wobei die mosaikartige Grundebene (**160**) dem angezeigten schrägen Bild überlagert und angepasst ist.

5. System nach einem der Ansprüche 1 bis 4, wobei die Bildanzeige- und -analyse-Software (**140**) nutzerauswählbare Messmodi umfasst, auf die durch Pulldown-Menüs, Symbolleisten und/oder Tastaturkommandos zugegriffen werden kann.

6. System nach einem der Ansprüche 1 bis 5, wobei jedes der Bilder von einer Bildaufnahmevorrichtung (**32a**, **32b**) und zu entsprechenden Bildaufnahmeereignissen aufgenommen wurden, wobei die Positionsdaten der Bild- und Datendatei umfassen:
Zeitdaten, die der Zeit jedes Bildaufnahmeereignisses entsprechen;
Positionsdaten, die dem Ort der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis entsprechen;
Ausrichtungsdaten, die der Ausrichtung der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis entsprechen;
Korrekturdaten, die Korrekturfaktoren für die Bildaufnahmevorrichtung (**32a**, **32b**) entsprechen; und
Höhenlagendaten, die einer durchschnittlichen Höhenlage der durch die Bildaufnahmevorrichtung (**32a**, **32b**) aufgenommenen Oberfläche entsprechen.

7. System nach Anspruch 6, wobei die Positionsdaten einen Breitengrad, einen Längengrad und eine Höhenlage der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis umfassen.

8. System nach Anspruch 6 oder 7, wobei die Ausrichtungsdaten ein Rollen, Stampfen, Gieren und eine Ausrichtung der Bildaufnahmevorrichtung (**32a**,

32b) zu jedem Bildaufnahmeereignis umfassen.

9. System nach einem der Ansprüche 6 bis 8, wobei die Bildaufnahmevorrichtung (**32a**, **32b**) eine Kamera ist und die Korrekturdaten eine Brennweite, eine Sensorgröße, ein Bildseitenverhältnis, einen Hauptpunktversatz, eine Verzerrung und/oder einen Bildpunktabstand umfassen.

10. System nach einem der Ansprüche 6 bis 9, umfassend:
eine Eingabevorrichtung (**134a**, **134b**) zum Auswählen eines Anfangspunkts und eines Endpunkts auf dem angezeigten schrägen Bild; und
die Bildanzeige- und -analyse-Software (**140**) zum Auslesen von Positionsdaten aus der Datendatei, die zu dem Anfangspunkt und dem Endpunkt gehören; zum Referenzieren der Grundebenendatei, die zur mosaikartigen Grundebene gehört, die eine Vielzahl von Facetten aufweist, wobei jede der Facetten einen zugehörige Abstand und Steigung aufweist, wobei die mosaikartige Grundebene mit einem Geländen des angezeigten schrägen Bildes nahezu übereinstimmt; zum Verbinden der Anfangs- und Endpunkte mit Linienabschnitten, wobei die Linienabschnitte an den Abstand und die Steigung der Facetten angepasst sind, um dem Gelände zu folgen; und zum Berechnen des geraden Abstands entlang der Liniensegmente zwischen den Anfangs- und Endpunkten, wobei der Abstand und die Steigung der Facetten berücksichtige werden.

11. System nach einem der Ansprüche 1 bis 10, wobei die Bildanzeige- und -analyse-Software (**140**) die mosaikartige Grundebene auf das angezeigte schräge Bild überlagert.

12. System nach Anspruch 10 oder 11, umfassend:
die Eingabevorrichtung (**134a**, **134b**) zum Auswählen eines oder mehrerer Zwischenpunkte auf dem angezeigten schrägen Bild; und
die Bildanzeige- und -analyse-Software (**140**) zum Auslesen von Positionsdaten aus der Datendatei, die zu dem einen oder den mehreren Zwischenpunkten gehören; zum Verbinden benachbarter Zwischenpunkte miteinander und zum Verbinden des Anfangs- und Endpunkts mit benachbarten Zwischenpunkten durch Linienabschnitte, wobei die Linienabschnitte an den Abstand und die Steigung der Facetten angepasst sind, um dem Gelände zu folgen; und zum Berechnen des Abstands entlang der Liniensegmente zwischen dem Anfangs- und dem Endpunkt.

13. System nach einem der Ansprüche 1 bis 12, wobei die Vielzahl der Facetten (**162a**, **162b**, **162c**, ...) jeweils gleichen Flächen des angezeigten schrägen Bildes entsprechen.

14. System nach einem der Ansprüche 1 bis 13, wobei die Vielzahl der Facetten (**162a**, **162b**, **162c**, ...) jeweils eine gleiche Zahl von Bildpunkten des angezeigten schrägen Bildes umfasst.

15. System nach einem der Ansprüche 1 bis 14, umfassend eine Eingabevorrichtung (**134a**, **134b**) zum Auswählen eines oder mehrerer Zwischenpunkte auf dem angezeigten schrägen Bild; und die Bildanzeige- und -analyse-Software (**140**) zum Auslesen der Positionsdaten, die zu den Zwischenpunkten gehören.

16. System nach einem der Ansprüche 1 bis 15, wobei der Abstand einen Abstand zwischen zwei oder mehr ausgewählten Punkten, einen Höhenunterschied zwischen zwei oder mehr ausgewählten Punkten, einen Höhenlagenunterschied zwischen zwei oder mehr ausgewählten Punkten und eine durch zumindest drei Punkte umfasste Fläche umfasst.

17. System nach einem der Ansprüche 1 bis 16, umfassend:
eine Bildaufnahmevorrichtung (**32a**, **32b**), wobei die Bildaufnahmevorrichtung (**32a**, **32b**) schräge Bilder zu Bildaufnahmeereignissen aufnimmt, wobei die Bildaufnahmevorrichtung (**32a**, **32b**) Bilddatensignale ausgibt, die den aufgenommenen Bildern entsprechen;
mindestens eine Erdpositionsbestimmungsvorrichtung (**34**, ..., **44**), wobei die mindestens eine Erdpositionsbestimmungsvorrichtung (**34**, ..., **44**) zumindest ein zugehöriges Erdpositionsbestimmungssignal ausgibt, wobei jedes der mindestens einen Erdpositionsbestimmungssignale zumindest teilweise eine Erdposition der Bildaufnahmevorrichtung (**32a**, **32b**) während jedes Bildaufnahmeereignisses anzeigt; und
ein Computersystem (**46**), das Bilddatensignale und das mindestens eine Erdpositionsbestimmungssignal empfängt und speichert;
Bild- und Datenaufnahme-Software (**90**), welche die Bilddatensignale und das mindestens eine Erdpositionsbestimmungssignal liest, wobei die Software (**90**) jedes Bilddatensignal mit einem zugehörigen mindestens einen Erdpositionsbestimmungssignal für jedes Bildaufnahmeereignis verknüpft.

18. System nach Anspruch 17, wobei die mindestens eine Erdpositionsbestimmungsvorrichtung und das mindestens ein Erdpositionsbestimmungssignal entsprechend umfassen:
eine Uhr (**38**), die Zeitdatensignale an das bildaufnehmende Computersystem (**46**) ausgibt, die einen Zeitpunkt jedes Bildaufnahmeereignisses angeben;
einen GPS-Empfänger (**34**), der GPS-Signale empfängt und Positionsdatensignale an das bildaufnehmende Computersystem (**46**) ausgibt, die einen Längengrad und einen Breitengrad der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereig-

nis angeben;
eine Trägheitsnavigationseinheit (**36**), die Geschwindigkeitsdatensignale an das bildaufnehmende Computersystem (**46**) ausgibt, die eine Geschwindigkeit der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis angeben;
ein Gyroskop (**40**), das ein Stampfsignal, ein Rollsignal und ein Giersignal an das bildaufnehmende Computersystem (**46**) ausgibt, die ein entsprechendes Stampfen, Rollen und Gieren zu jedem Bildaufnahmeereignis angeben;
einen Kompass (**42**), der Ausrichtungsdatensignale an das bildaufnehmende Computersystem (**46**) ausgibt, die eine Ausrichtung der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis angeben; und/oder
einen Höhenmesser (**44**), der Höhenlagendatensignale an das bildaufnehmende Computersystem (**46**) ausgibt, die eine Höhenlage der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis angeben.

19. System nach Anspruch 17 oder 18, weiterhin umfassend Korrekturdaten, die Eigenschaften der Bildaufnahmevorrichtung (**32a**, **32b**) angeben, einschließlich Brennweite, Sensorgröße, radiale Verzerrung, Hauptpunktversatz und Ausrichtung, wobei die Bild- und Datenaufnahme-Software (**90**) die Korrekturdaten verwendet, um aufgenommene Bilder zu korrigieren.

20. System nach einem der Ansprüche 17 bis 19, weiterhin umfassend eine Ausgabedatendatei, die durch die Bild- und Datenaufnahme-Software (**90**) erzeugt wird, wobei die Ausgabedatendatei eine Vielzahl von Bilddateien und zu der Vielzahl von Bilddateien gehörige Positionsdaten umfasst.

21. System nach einem der Ansprüche 17 bis 19, weiterhin umfassend eine Plattform (**20**) zum Tragen der Bildaufnahmevorrichtung (**32a**, **32b**) um einen vorbestimmten Anstand oberhalb der von Interesse seienden Oberfläche.

22. System nach Anspruch 21, wobei die Bildaufnahmevorrichtung (**32a**, **32b**) schräge Bilder einer von Interesse seienden Fläche als die schrägen Bilder aufnimmt mittels:
Unterteilen der von Interesse seienden Fläche (**200**) in eine Vielzahl von Sektoren (**202a**, **202b**, **202c**);
Führen der Plattform (**20**) entlang eines ersten Pfads (**202**), um so mit der Bildaufnahmevorrichtung (**32a**, **32b**) auf einen oder mehrere Zielsektoren zu zielen;
Aufnehmen eines oder mehrerer schräger Bilder mit der Bildaufnahmevorrichtung (**32a**, **32b**), um damit eine Gesamtheit jedes der Zielsektoren mit schrägen Bildern, die aus einer ersten Perspektive aufgenommen werden, abzudecken;
Führen der Plattform (**20**) eines zweiten Pfads (**204**), um so auf die Zielsektoren zu zielen;
Aufnehmen eines oder mehrerer schräger Bilder mit der Bildaufnahmevorrichtung (**32a**, **32b**), um damit eine Gesamtheit jedes der Zielsektoren mit schrägen Bildern, die aus einer zweiten Perspektive aufgenommen werden, abzudecken;
Wiederholen der Führungs- und Aufnahmeschritte entlang von Pfaden, die im wesentlichen parallel und beabstandet von dem ersten und zweiten Pfad (**202**, **204**) liegen, und Aufnehmen eines oder mehrerer schräger Bilder, um damit eine Gesamtheit jedes der Vielzahl der Zielsektoren mit schrägen Bilder, die sowohl aus der ersten als auch aus der zweiten Perspektive aufgenommen werden, abzudecken; und
Aufnehmen von Positionsdaten, die eine Erdposition der Bildaufnahmevorrichtung (**32a**, **32b**) zu jedem Bildaufnahmeereignis anzeigen.

23. System nach Anspruch 22, wobei der zweite Pfad (**204**) im wesentlichen parallel zum und um 180° (einhundertachtzig Grad) gedreht zum ersten Pfad (**202**) liegt.

24. System nach Anspruch 23, wobei der zweite Pfad (**204**) vom ersten Pfad (**202**) auch beabstandet ist.

25. System nach einem der Ansprüche 22 bis 24, wobei
die Plattform (**20**) entlang eines dritten Pfads (**206**) geführt wird, um so mit der Bildaufnahmevorrichtung (**32a**, **32b**) auf einen oder mehrere Zielsektoren zu zielen, wobei der dritte Pfad (**206**) im wesentlichen senkrecht zum dem ersten und dem zweiten Pfad (**202**, **204**) liegt;
die Bildaufnahmevorrichtung (**32a**, **32b**) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes Zielsektors mit schrägen Bildern, die aus einer dritten Perspektive aufgenommen werden, abzudecken; wobei
die Plattform (**20**) geführt wird und die Bildaufnahmevorrichtung (**32a**, **32b**) die schrägen Bilder entlang von Pfaden aufnimmt, der im wesentlichen parallel und beabstandet von dem dritten Pfad (**306**) liegen; und
wobei die Bildaufnahmevorrichtung (**32a**, **32b**) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes aus der Vielzahl der Zielsektoren mit schrägen Bildern, die aus der dritten Perspektive aufgenommen werden, abzudecken.

26. System nach Anspruch 25, wobei
die Plattform (**20**) entlang eines vierten Pfads (**208**) geführt wird, um so mit der Bildaufnahmevorrichtung (**32a**, **32b**) auf einen oder mehrere Zielsektoren zu zielen, wobei der vierte Pfad (**208**) im wesentlichen parallel zum und um 180° (einhundertachtzig Grad) gedreht zum dritten Pfad (**206**) liegt;
die Bildaufnahmevorrichtung (**32a**, **32b**) ein oder mehrere schräge Bilder aufnimmt, um damit eine Gesamtheit jedes Zielsektors mit schrägen Bildern, die

aus einer vierten Perspektive aufgenommen werden, abzudecken; und
die Führungs- und Aufnahmeschritte entlang von Pfaden wiederholt werden, die im wesentlichen parallel zu und beabstandet von dem vierten Pfad (**208**) liegen, und Aufnehmen eines oder mehrerer schräger Bilder, um damit eine Gesamtheit jedes der Vielzahl der Zielsektoren mit schrägen Bilder, die aus der vierten Perspektive aufgenommen werden, abzudecken.

27. System nach Anspruch 26, wobei der vierte Pfad (**208**) von dem dritten Pfad (**206**) auch beabstandet ist.

Es folgen 10 Blatt Zeichnungen

Anhängende Zeichnungen

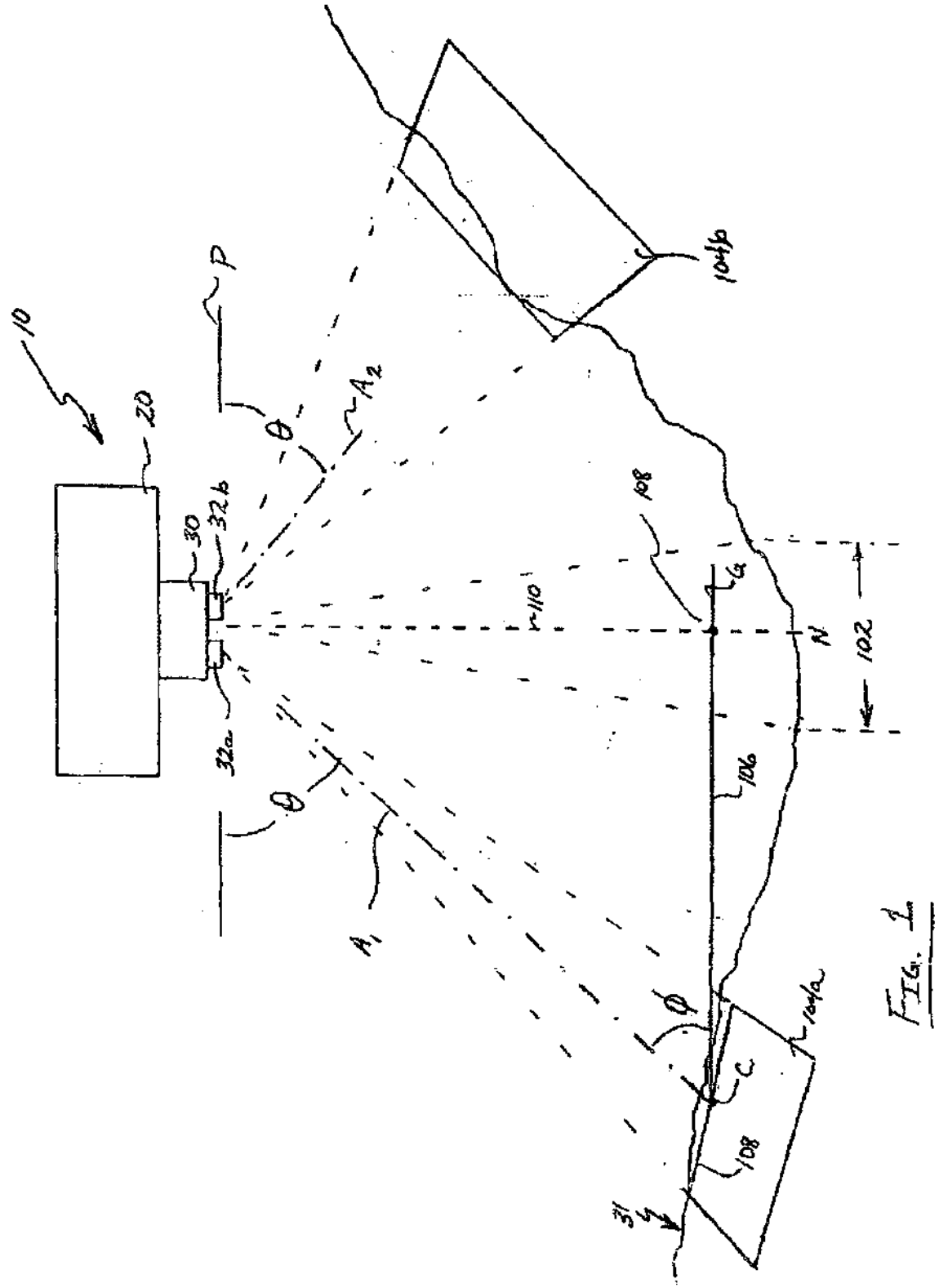


FIG. 1

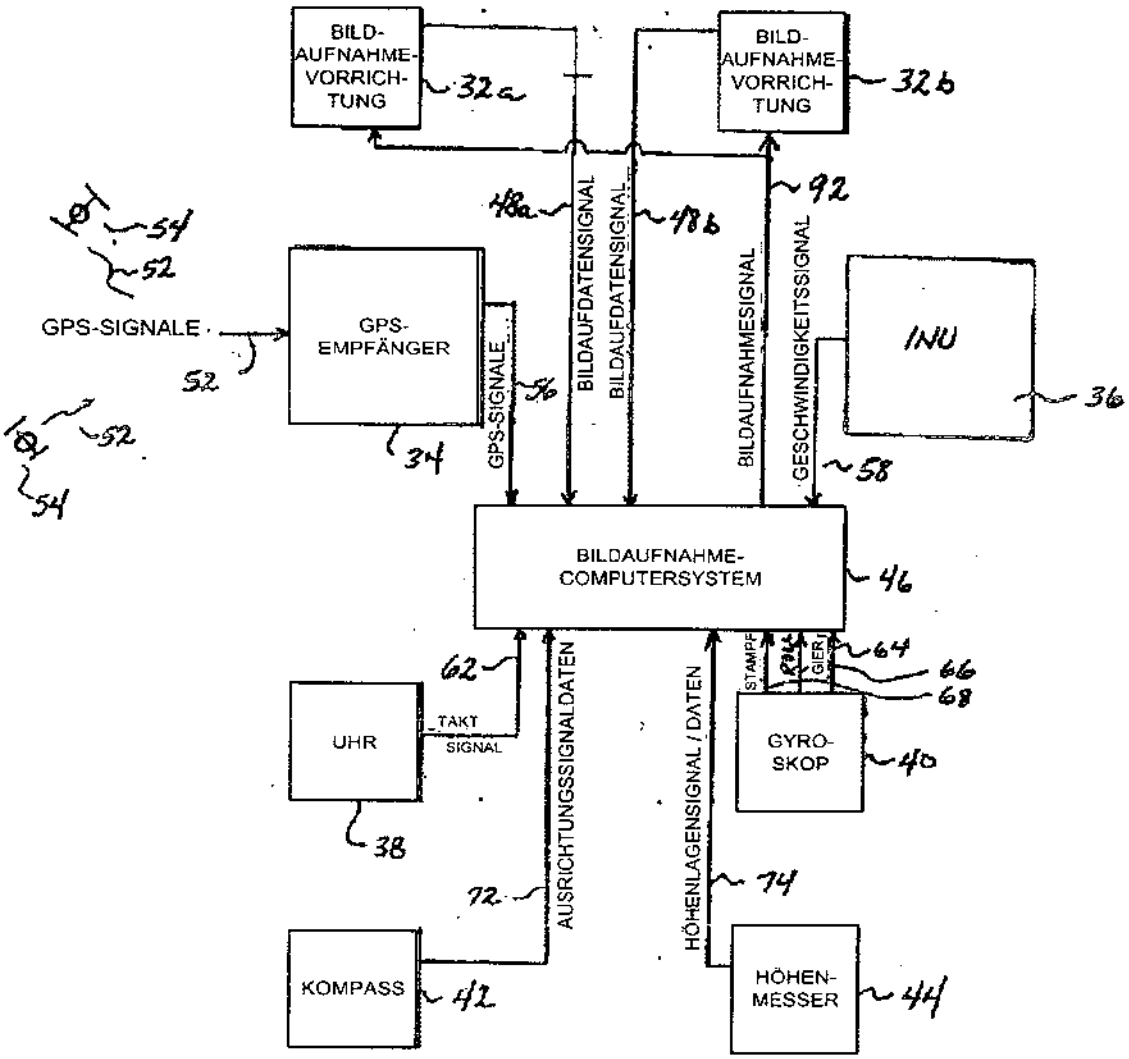

BILD-AUFNAHME-VORRICH-TUNG
32a
BILD-AUFNAHME-VORRICH-TUNG
32b
48a
48b
92
BILDAUFDATENSIGNAL
BILDAUFDATENSIGNAL
BILDAUFNAHMESIGNAL
GESCHWINDIGKEITSSIGNAL
54
52
GPS-SIGNALE
52
GPS-EMPFÄNGER
34
GPS-SIGNALE
56
INU
36
58
52
54
BILDAUFNAHME-COMPUTERSYSTEM
46
62
TAKT SIGNAL
UHR
38
64
66
68
STAMPF
ROLL
GIER
GYRO-SKOP
40
72
AUSRICHTUNGSSIGNALDATEN
74
HÖHENLAGENSIGNAL / DATEN
KOMPASS
42
HÖHEN-MESSER
44

FIG. 2

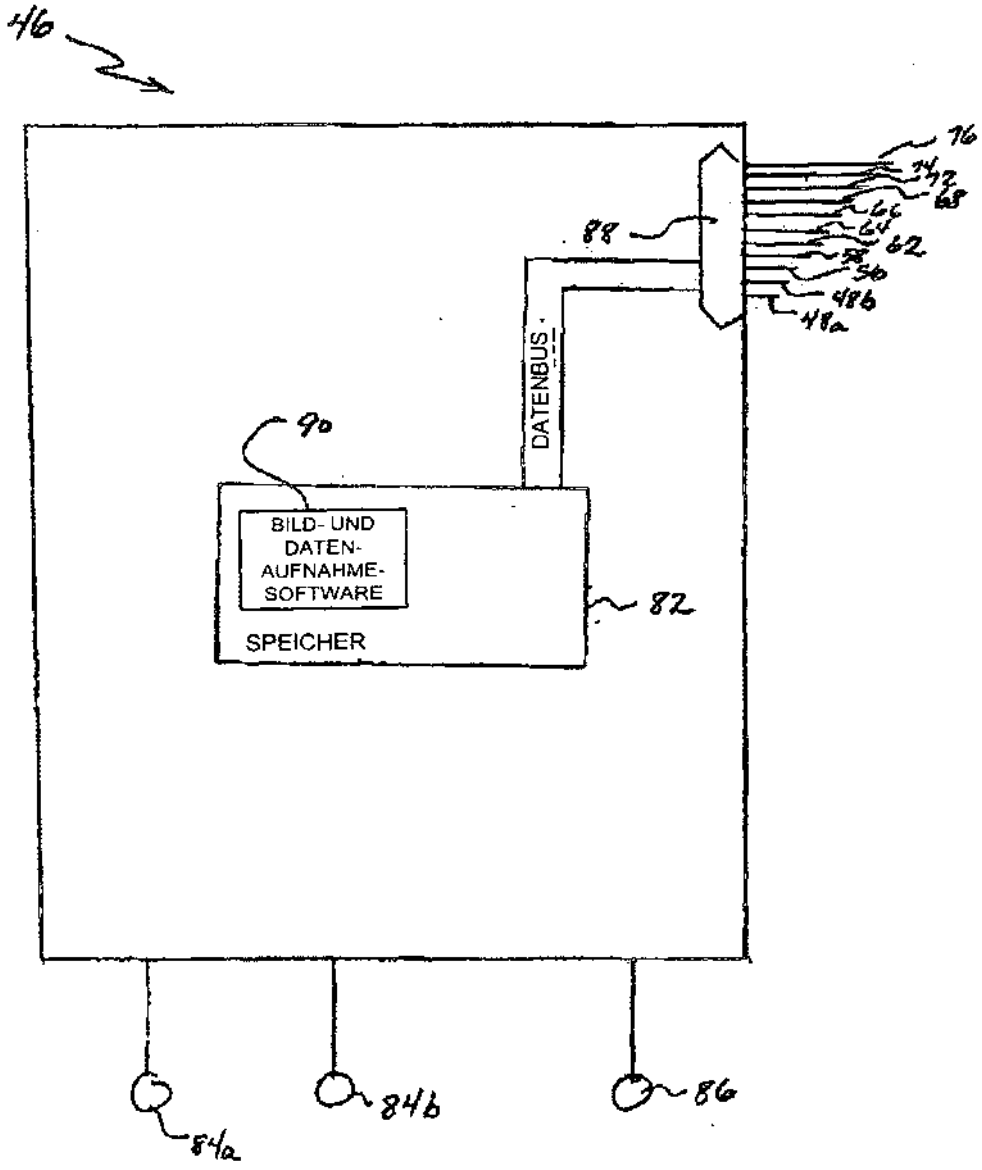

46
76
74
72
68
66
64
62
58
50
48b
48a
88
DATENBUS
90
BILD- UND
DATEN-
AUFNAHME-
SOFTWARE
SPEICHER
82
84a
84b
86

FIG. 3

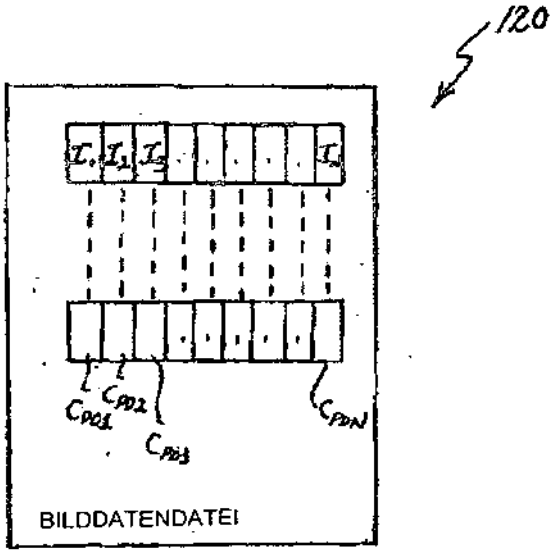


FIG. 4

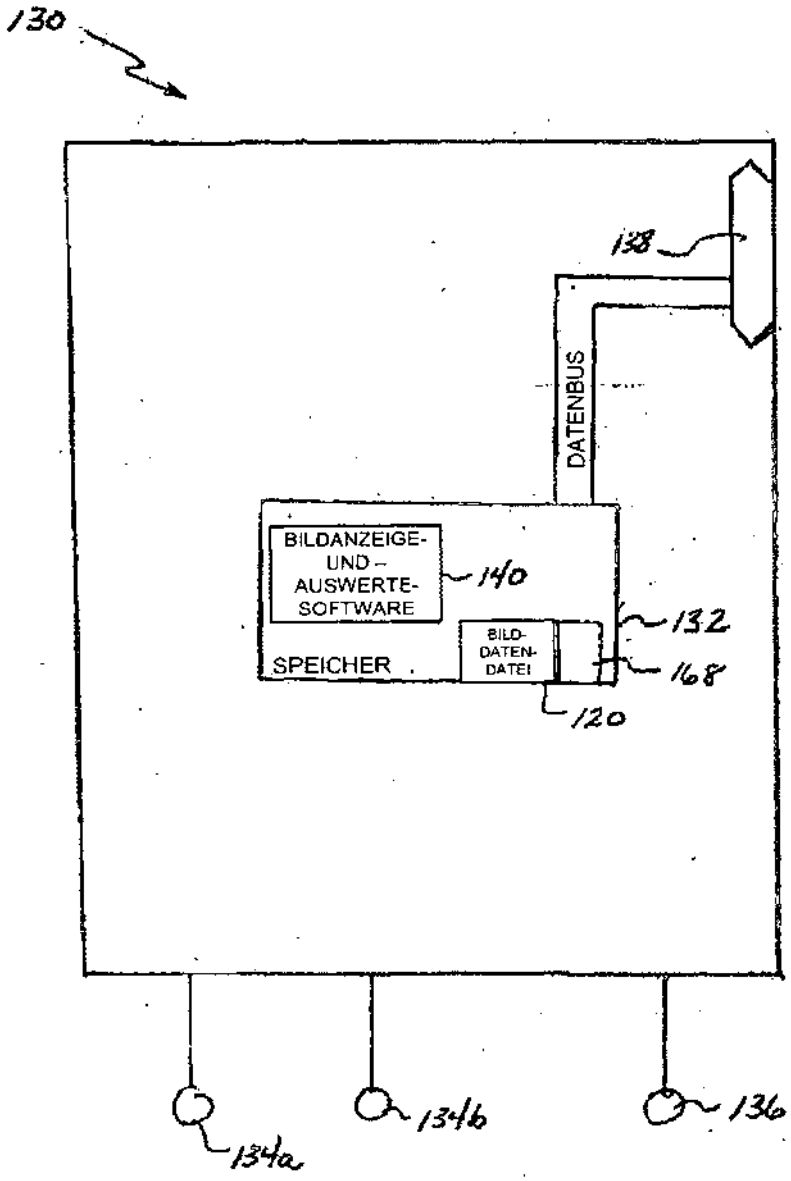

130
138
DATENBUS
BILDANZEIGE-
UND-
AUSWERTE-
SOFTWARE
140
SPEICHER
BILD-
DATEN-
DATEI
132
168
120
134a
134b
136

FIG. 5

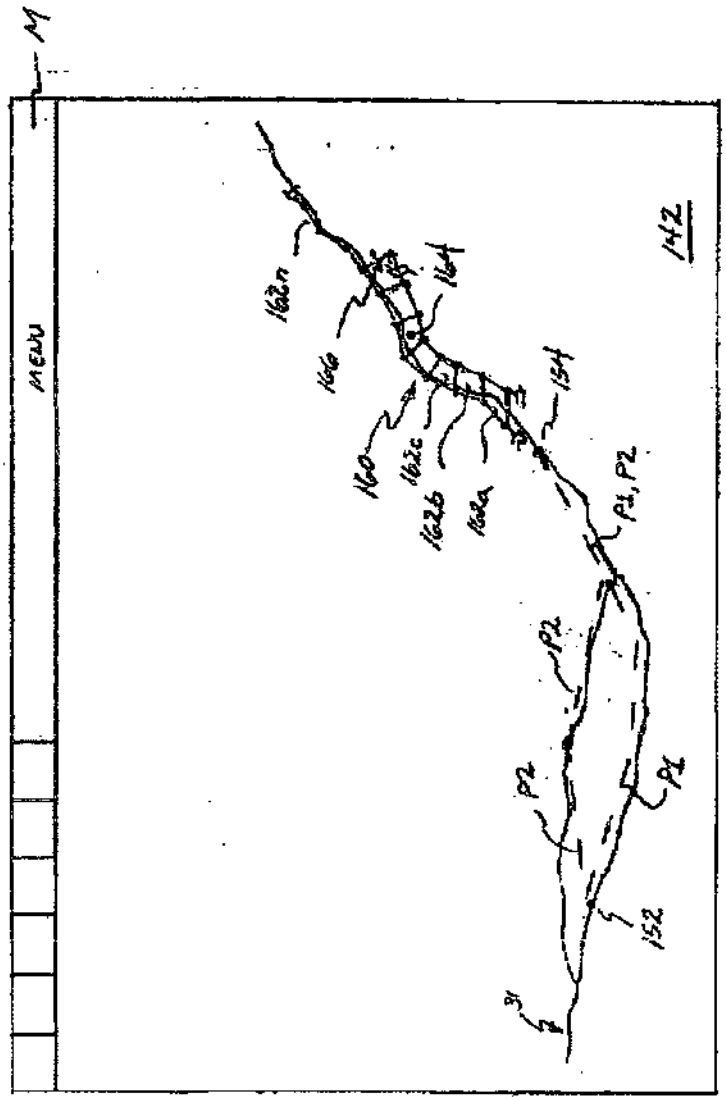


FIG. 6

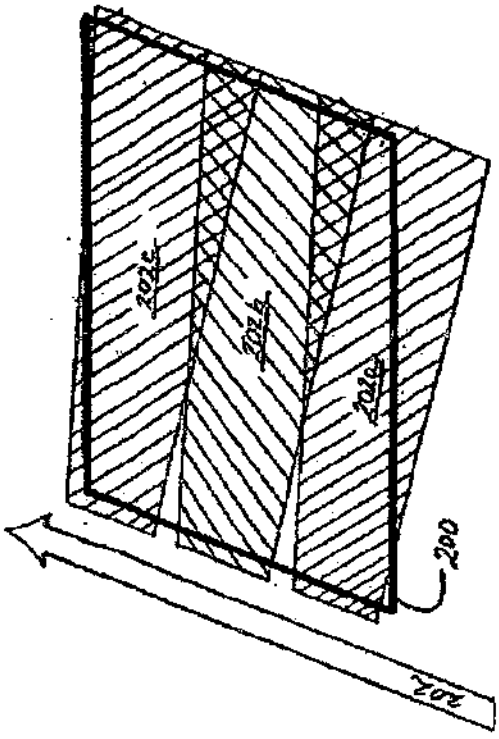


Fig. 1

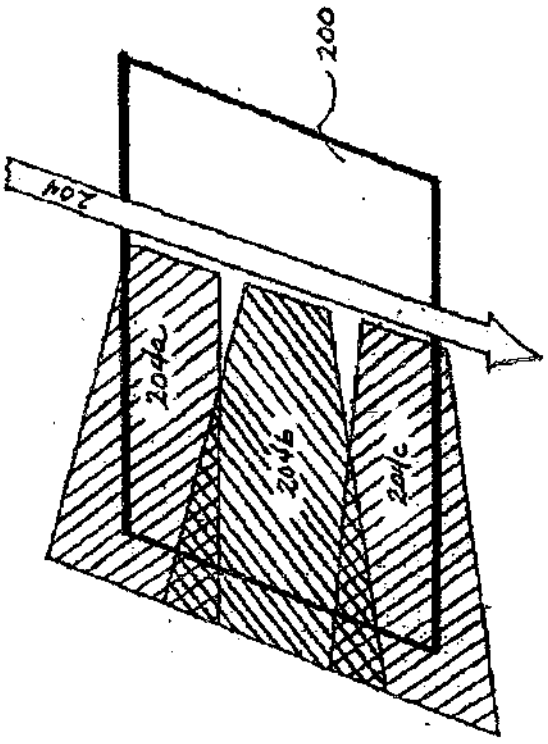


FIG. 8

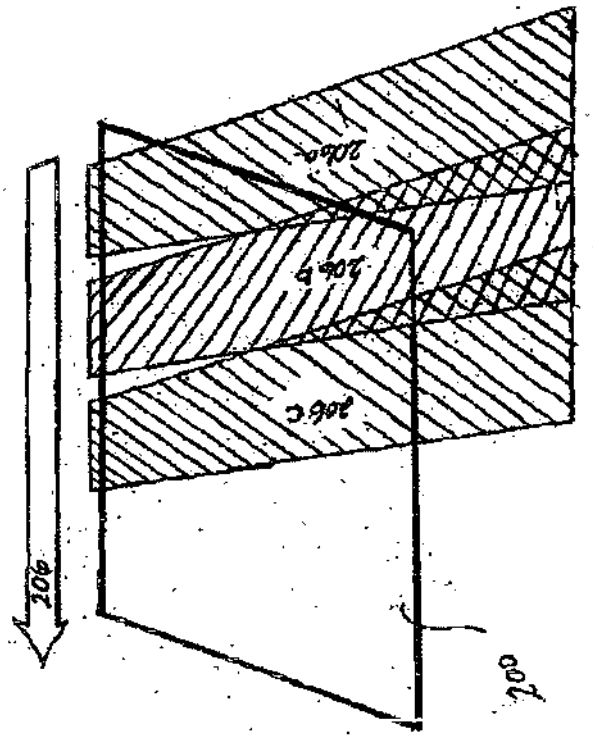


Fig. 9

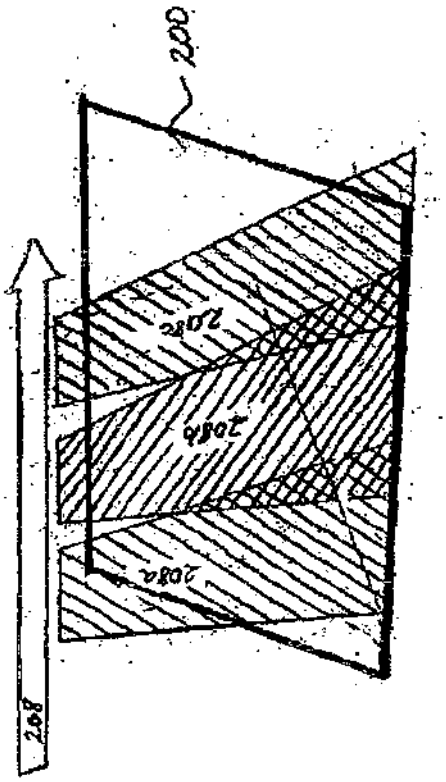


Fig. 10

(19) OFICINA ESPAÑOLA DE PATENTES Y MARCAS

ESPAÑA

(11) Número de publicación: **2 266 704**

(51) Int. Cl.:
G01C 11/02 (2006.01)

(12) TRADUCCIÓN DE PATENTE EUROPEA T3

(86) Número de solicitud europea: **03025702 .6**
(86) Fecha de presentación : **07.11.2003**
(87) Número de publicación de la solicitud: **1418402**
(87) Fecha de publicación de la solicitud: **12.05.2004**

(54) Título: **Procedimiento y aparato para capturar, geolocalizar y medir imágenes oblicuas.**

(30) Prioridad: **08.11.2002 US 425275 P**

(45) Fecha de publicación de la mención BOPI:
01.03.2007

(45) Fecha de la publicación del folleto de la patente:
01.03.2007

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ES 2 266 704 T3

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DESCRIPCIÓN

Procedimiento y aparato para capturar, geolocalizar y medir imágenes oblicuas.

Referencias cruzadas a aplicaciones relacionadas

Esta solicitud reivindica el beneficio de la solicitud de patente provisional norteamericana número de serie 60/425.275, presentada el 8 de noviembre de 2002.

Campo técnico

La presente invención se refiere a la fotogrametría. Más en particular, la presente invención se refiere a un procedimiento y aparato para capturar imágenes oblicuas y para medir los objetos y las distancias entre los objetos que se muestran en las mismas.

Antecedentes

La fotogrametría es la ciencia de realizar mediciones de y entre objetos mostrados en fotografías, especialmente en fotografías aéreas. En general, la fotogrametría incluye tomar imágenes de características terrestres y obtener como resultado datos de las mismas, tales como, por ejemplo, datos indicativos de las distancias relativas entre los objetos y sus tamaños en las imágenes. La fotogrametría también puede incluir acoplar las fotografías a otros datos, tales como datos representativos de la latitud y de la longitud. En efecto, la imagen se superpone y se conforma a un sistema de coordenadas espaciales particular.

La fotogrametría convencional incluye la captura y/o la adquisición de imágenes ortogonales. El dispositivo de captura de imágenes, tal como una cámara o sensor, se transporta en un vehículo o plataforma, tal como un aeroplano o satélite, y se enfoca a un punto nadir que está directamente debajo y/o verticalmente hacia abajo desde esa plataforma. El punto o píxel en la imagen que se corresponde al punto nadir es el único punto/píxel que es verdaderamente ortogonal al dispositivo de captura de imágenes. Todos los otros puntos o píxeles en la imagen son, en realidad, oblicuos con relación al dispositivo de captura de imágenes. Cuando los puntos o píxeles se hacen crecientemente distantes del punto nadir, se hacen crecientemente oblicuos con relación al dispositivo de captura de imágenes y también se incrementa la distancia de la muestra de suelo (es decir, el área superficial que se corresponde o que está cubierta por cada píxel). Tal oblicuidad en una imagen ortogonal hace que las características en la imagen queden distorsionadas, especialmente imágenes relativamente distantes del punto nadir.

Una perturbación de este tipo se elimina, o se compensa, por el proceso de ortorectificación, en el cual, en esencia, elimina la oblicuidad de la imagen ortogonal ajustando o deformando cada píxel de una imagen ortogonal en una rejilla ortométrica o sistema coordenado. El procedimiento de la ortorectificación crea una imagen en la que todos los píxeles tienen la misma distancia de muestra de suelo y están orientados al norte. De esta manera, cualquier punto en una imagen ortorectificada puede ser localizado utilizando el sistema de coordenadas X, Y y, siempre que la escala de la imagen sea conocida, pueden ser calculadas la longitud y la anchura de las características terrestres así como la distancia relativa entre estas características.

Aunque el proceso de ortorectificación compensa hasta un cierto grado las distorsiones oblicuas en una imagen ortogonal, introduce otras distorsiones y/o inexactitudes indeseables en la imagen ortogonal ortorectificada. Los objetos mostrados en las imágenes ortogonales ortorectificadas pueden ser difíciles de reconocer y/o identificar puesto que la mayor parte de los observadores no están acostumbrados a visualizar objetos, particularmente características terrestres, desde arriba. Para un observador no entrenado, una imagen ortorectificada presenta un número de distorsiones. Las carreteras que en realidad son rectas aparecen curvadas y los edificios parecen inclinarse. Además, las imágenes ortorectificadas no contienen sustancialmente ninguna información respecto a la altura de las características terrestres. La interpretación y el análisis de imágenes ortogonales y/o ortogonales ortorectificadas típicamente son efectuadas por analistas altamente cualificados que poseen años de entrenamiento especializado y experiencia para identificar objetos y características terrestres en tales imágenes.

De esta manera, aunque las imágenes ortogonales y ortorectificadas son útiles en la fotogrametría, les falta información referente a la altura de las características mostradas en ellas y requieren analistas altamente entrenados para interpretar los detalles a partir de lo que muestran las imágenes.

Las imágenes oblicuas son imágenes que han sido capturadas con un dispositivo de captura de imágenes enfocado o apuntado generalmente a un lado o hacia abajo de la plataforma que transporta el dispositivo de captura de imágenes. Las imágenes oblicuas, a diferencia de las imágenes ortogonales, muestran lados de las características terrestres, tales como casas, edificios y/o montañas, así como las partes superiores de las mismas. De esta manera, visualizar una imagen oblicua es más natural e intuitivo que visualizar una imagen ortogonal u ortorectificada, e incluso los observadores casuales pueden reconocer e interpretar características terrestres y otros objetos mostrados en las imágenes oblicuas. Cada píxel en el primer plano de una imagen oblicua se corresponde a un área relativamente pequeña de la superficie o del objeto mostrado (es decir, cada píxel de primer plano tiene una distancia de muestra de suelo relativamente pequeña) mientras que cada píxel en el plano de fondo se corresponde a un área relativamente grande de la superficie o del objeto mostrado (es decir, cada píxel de plano de fondo tiene una distancia de muestra de suelo relativamente grande). Las imágenes oblicuas capturan un área generalmente trapezoidal o una vista de la superficie del sujeto o un objeto, teniendo el primer plano del trapezoide una distancia de muestra de suelo sustancialmente menor (es decir, una resolución más elevada) que el plano de fondo del trapezoide.

Se considera que las imágenes oblicuas son de poca o ninguna utilidad en la fotogrametría. El enfoque convencional de forzar los píxeles de primer plano y de plano de fondo de distintos tamaño de una imagen oblicua en un tamaño uniforme para deformar de esta manera la imagen en un sistema de coordenadas distorsiona en gran medida la imagen oblicua y por lo tanto, impide la identificación de los objetos y la toma de medidas de los objetos mostrados y hace que esto sea una tarea laboriosa e inexacta. La corrección de los desplazamientos del terreno dentro de una imagen oblicua utilizando un modelo de elevación distorsiona adicionalmente las imágenes, con lo cual incrementa la dificultad con la que se pueden realizar las mediciones y reduce la precisión de tales mediciones.

Como consecuencia, aunque se considera que las

imágenes oblicuas tienen poca, o ninguna, utilidad en la fotogrametría, son fácilmente interpretadas y contienen información referente a la altura de las características mostradas en las mismas. El documento WO 99/18732 A1 muestra un sistema y procedimiento para capturar, geolocalizar y medir imágenes oblicuas, que comprende un dispositivo de captura de imágenes, un dispositivo de geolocalización, un sistema de ordenador y un software de adquisición de imágenes y datos, que asocia los datos de imágenes a los datos de la señal de geolocalización.

Objeto de la invención

Por lo tanto, lo que se precisa en la técnica es un procedimiento y aparato para la fotogrametría que permita la geolocalización y las mediciones precisas en imágenes oblicuas.

Además, lo que se necesita en la técnica es un procedimiento y aparato para la fotogrametría que permita la medición de alturas y de alturas relativas de los objetos dentro de una imagen.

Además, lo que se necesita en la técnica es un procedimiento y aparato para la fotogrametría que utilice imágenes más intuitivas y naturales.

Sumario de la invención

La presente invención proporciona un sistema de acuerdo con la reivindicación 1.

Breve descripción de los dibujos

Las características de esta invención que se han mencionado más arriba, así como otras, y la manera de conseguirlas, serán evidentes y más completamente comprensibles haciendo referencia a la descripción que sigue de una realización de la invención, cuando se lee en conjunto con los dibujos que se acompañan, en los cuales:

La figura 1 ilustra una realización de una plataforma o vehículo que transporta un sistema de captura de imágenes de la presente invención, y muestra imágenes ejemplares ortogonales y oblicuas tomadas por medio del mismo;

La figura 2 es una vista diagramática del sistema de captura de imágenes de la figura 1;

La figura 3 es un diagrama de bloques del sistema de ordenador de captura de imágenes de la figura 2;

La figura 4 es una representación de un archivo de datos de salida ejemplar del sistema de captura de imágenes de la figura 1;

La figura 5 es un diagrama de bloques de una realización de un sistema de una pantalla de imágenes y de ordenador de medición de la presente invención, para mostrar y tomar medidas de y entre los objetos mostrados en las imágenes capturadas por el sistema de captura de imágenes de la figura 1;

La figura 6 muestra una imagen ejemplar mostrada del sistema de la figura 5, e ilustra una realización del procedimiento de la presente invención para la medida de, y entre, objetos mostrados en una imagen de este tipo;

Las figuras 7 y 8 ilustran una realización de un procedimiento para capturar imágenes oblicuas de la presente invención;

Las figuras 9 y 10 ilustran una segunda realización de un procedimiento para capturar imágenes oblicuas de la presente invención.

Los caracteres de referencia correspondientes indican elementos correspondientes en las distintas vistas. Las ejemplarizaciones establecidas en la presente memoria descriptiva ilustran una realización preferente de la invención, en una forma, y tales ejemplarizaciones no deben considerarse como limitativas del alcance de la invención de ninguna manera.

Descripción de las realizaciones preferentes

Haciendo referencia a continuación a los dibujos, y en particular a la figura 1, se muestra una realización de un aparato para capturar y geolocalizar imágenes oblicuas de la presente invención. El aparato 10 incluye una plataforma o vehículo 20 que transporta un sistema 30 de captura de imágenes y de geolocalización.

La plataforma 20, tal como, por ejemplo, un aeroplano, trasbordador espacial, cohete, satélite o cualquier otro vehículo adecuado, transporta el sistema 30 de captura de imágenes sobre un área predefinida de una superficie 31 y a una o más altitudes predeterminadas sobre la misma, tal como, por ejemplo, la superficie de la tierra o cualquier otra superficie de interés. Como tal, la plataforma 20 puede controlar el movimiento o vuelo, ya sea tripulado o no tripulado, a lo largo de un trayecto o curso de vuelo predefinido, por ejemplo, la atmósfera de la tierra o el espacio exterior. La plataforma 20 de captura de imágenes incluye un sistema (no mostrado) para generar y regular la potencia que incluye, por ejemplo, uno o más generadores, células de combustible, paneles solares y/o baterías para energizar el sistema 30 de captura de imágenes.

El sistema 30 de captura de imágenes y de geolocalización, como mejor se muestra en la figura 2, incluye dispositivos 32a y 32b de captura de imágenes, un receptor 34 de un sistema de posicionado global (GPS), una unidad de navegación inercial (INU) 36, reloj 38, giroscopio 40, brújula 42 y altímetro 44, cada uno de los cuales está interconectado con el sistema 46 de ordenador de captura de imágenes.

Los dispositivos 32a y 32b de captura de imágenes tales como, por ejemplo, cámaras convencionales, cámaras digitales, sensores digitales, dispositivos acoplados en carga, u otros dispositivos adecuados de captura de imágenes, pueden capturar imágenes fotográfica o electrónicamente. Los dispositivos 32a y 32b de captura de imágenes tienen características conocidas o determinables que incluyen longitud focal, tamaño del sensor y relación de aspecto, términos radiales y de distorsión, punto principal de desplazamiento, paso de píxel, y alineación. Los dispositivos 32a y 32b de captura de imágenes adquieren imágenes y emiten señales de datos de imagen (IDS) 48a y 48b, respectivamente, que se corresponden a las imágenes particulares o fotografías tomadas y que se almacenan en el sistema 48 de ordenador de captura de imágenes, como será descrito más en particular en la presente memoria descriptiva posteriormente.

Como mejor se muestra en la figura 1, los dispositivos 32a y 32b de captura de imágenes tienen ejes centrales respectivos A_1 y A_2, y están montados en la plataforma 20 de manera que cada uno de los ejes A_1 y A_2 tenga un ángulo de declinación θ relativo al plano horizontal P. El ángulo de declinación θ es virtualmente cualquier ángulo oblicuo, pero preferiblemente es desde aproximadamente 20° (veinte grados) hasta aproximadamente 60° (sesenta grados) y más preferiblemente, desde aproximadamente 40° (cuarenta grados) a aproximadamente 50° (cincuenta grados).

El receptor GPS 34 recibe las señales 52 del sistema de posicionamiento global que son transmitidas por uno o más satélites 54 del sistema de posicionamiento global. Las señales GPS 52, de una manera conocida, permiten la localización precisa de la pla-

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taforma 20 con relación a la superficie 31 que se determine. El receptor GPS 34 descodifica las señales GPS 52 y emite señales/datos 56 de localización, que dependen, al menos en parte, de las señales GPS 52 y que son indicativas de la localización precisa de la plataforma 20 con relación a la superficie 31. Las señales/datos de localización 56 que se corresponden a cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes se reciben y se almacenan en el sistema 46 de ordenador de captura de imágenes.

La INU 36 es una unidad de navegación inercial convencional que está acoplada y detecta cambios en la velocidad, incluyendo velocidad de traslación y de rotación, de los dispositivos 32a y 32b de captura de imágenes y/o de la plataforma 20. La INU 36 emite señales/datos 58 de velocidad indicativas de tales velocidades y/o cambios del sistema 46 de ordenador de captura de imágenes, que almacena las señales/datos de velocidad 58 que se corresponden a cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes y se reciben y almacenan en el sistema 46 de ordenador de captura de imágenes.

El reloj 38 mantiene una medida de tiempo precisa (tiempo de validez) que se utiliza para sincronizar los sucesos dentro del sistema 30 de captura de imágenes y de geolocalización. El reloj 38 proporciona la señal 62 de momento de datos/reloj que son indicativas del momento preciso en el que se tomó una imagen por medio de los dispositivos 32a y 32b de captura de imágenes. Los datos de momento 62 también se proporcionan y se almacenan en el sistema 46 de ordenador de captura de imágenes. Alternativamente, el reloj 38 es integral con el sistema 46 de ordenador de captura de imágenes, tal como, por ejemplo, un programa de software de reloj.

El giroscopio 40 es un giroscopio convencional, como se encuentra comúnmente en aeroplanos y/o en sistemas de navegación comercial para aeroplanos. El giroscopio 40 proporciona señales que incluyen la señal 64 de inclinación longitudinal, la señal 66 de balanceo y la señal 68 de guiñada, que respectivamente son indicativas de la inclinación longitudinal, balanceo y guiñada de la plataforma 20. La señal 64 de inclinación longitudinal, la señal 66 de balanceo y la señal 68 de guiñada que se corresponden a cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes se reciben y almacenan en el sistema 46 de ordenador de captura de imágenes.

La brújula 42, tal como, por ejemplo, una brújula electrónica convencional, indica el rumbo de la plataforma 20. La brújula 42 emite señales/datos 72 de rumbo que son indicativos del rumbo de la plataforma 20. El sistema 46 de ordenador de captura de imágenes recibe y almacena las señales/datos 72 de rumbo que se corresponden a cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes.

El altímetro 44 indica la altitud de la plataforma 20. El altímetro 44 emite señales/datos 74 de altitud y el sistema 46 de ordenador de captura de imágenes recibe y almacena las señales/datos de altitud 74 que se corresponden a cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes.

Como mejor se muestra en la figura 3, el sistema 46 de ordenador de captura de imágenes, tal como, por ejemplo, un ordenador personal portátil convencional, incluye memoria 82, dispositivos de entrada 84a y 84b, dispositivo de pantalla 86, y puertos de entrada y salida 88 (I/O). El sistema 46 de ordenador de captura de imágenes ejecuta el software 90 de adquisición de imágenes y datos, que está almacenado en la memoria 82. La memoria 82 también almacena datos utilizados y/o calculados por el sistema 46 de ordenador de captura de imágenes durante la operación del mismo, e incluye, por ejemplo, memoria no volátil de solo lectura, memoria de acceso aleatorio, memoria de disco duro, tarjetas de memoria retirables y/o otros dispositivos y/o medios de almacenamiento de memoria adecuados. Los dispositivos 84a y 84b de entrada, tales como, por ejemplo, un ratón, tablero, palanca de control u otros dispositivos de entrada similares, permiten la introducción de datos y la interacción de un usuario con el software que está siendo ejecutado por el sistema 46 de ordenador de captura de imágenes. El dispositivo 86 de pantalla, tal como, por ejemplo, una pantalla de cristal líquido o un tubo de rayos catódicos, muestra información al usuario del sistema 46 de ordenador de captura de imágenes. Los puertos I/O 88, tales como, por ejemplo, puertos de entrada y salida de datos serie y paralelo, permiten la introducción y la salida de datos a y desde el sistema 46 de ordenador de captura de imágenes.

Cada una de las señales de datos que se han descrito más arriba se conecta al sistema 46 de ordenador de captura de imágenes. Más en particular, las señales 48 de datos de imágenes, las señales 56 de localización, las señales 58 de velocidad, la señal 62 de dato de tiempo, las señales 64, 66 y 68 de inclinación longitudinal, balanceo y guiñada respectivamente, la señal 72 de rumbo, y la señal 74 de altitud se reciben por medio de los puertos I/O 88 y se almacenan en la memoria 82 del sistema 46 de ordenador de captura de imágenes.

En uso, el sistema 46 de ordenador de captura de imágenes ejecuta el software 90 de adquisición de imágenes y datos que, en general, controla la lectura, manipulación y almacenamiento de las señales de datos que se ha descrito más arriba. Más en particular, el software 90 de adquisición de imágenes y datos lee las señales 48a y 48b de datos de imágenes y las almacena en la memoria 82. Cada una de las señales 56 de localización, señales 58 de velocidad, señales 62 de datos de tiempo, señales de inclinación longitudinal, balanceo y guiñada 64, 66 y 68, respectivamente, señal de rumbo 72 y señal de altitud 74, que representan las condiciones existentes en el momento en que se adquirió o capturó una imagen por los dispositivos 32a y 32b de captura de imágenes y que se corresponden a las señales 48a y 48b de datos de imágenes particulares que representan las imágenes capturadas, son recibidas por el sistema 46 de ordenador de captura de imágenes por medio de los puertos de I/O 88. El sistema 46 de ordenador de captura de imágenes que ejecuta software 90 de adquisición de imágenes y datos emite una señal 92 de captura de imágenes a los dispositivos 32a y 32b de captura de imágenes para hacer de esta manera que estos dispositivos adquieran o capturen una imagen en localizaciones predeterminadas y/o en intervalos predeterminados que dependen, al menos en parte, de la velocidad de la plataforma 20.

El software 90 de adquisición de imágenes y datos descodifica como sea necesario y almacena las señales que se han mencionado con anterioridad en la memoria 82, y asocia las señales de datos a las señales 48a y 48b de imágenes correspondientes. De esta manera, la altitud, rumbo en términos de inclinación

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longitudinal, balanceo y guiñada, y la localización de los dispositivos 32a y 32b de captura de imágenes en relación con la superficie, es decir, longitud y latitud, de cada imagen capturada por los dispositivos 32a y 32b de captura de imágenes, es conocida.

La plataforma 20 es pilotada o guiada de otra manera a lo largo de un trayecto de captura de imágenes que pasa sobre un área particular de la superficie 31, tal como, por ejemplo, un área predefinida de la superficie de la tierra o de otro planeta. Preferiblemente, el trayecto de captura de imágenes de la plataforma 20 se encuentra en ángulo recto respecto, al menos, uno de los límites del área de interés. El número de veces que la plataforma 20 y/o los dispositivos 32a, 32b de captura de imágenes pasa sobre el área de interés depende de, al menos en parte, el tamaño del área y la cantidad de detalles deseados en las imágenes capturadas. Los detalles particulares del trayecto de captura de imágenes de la plataforma 20 se describen de manera más particular en la presente memoria y a continuación.

Cuando la plataforma 20 pasa sobre el área de interés, es capturado un número de imágenes oblicuas por los dispositivos 32a y 32b de captura de imágenes. Como podrán entender aquellos de conocimiento ordinario en la técnica, las imágenes son capturadas o adquiridas por los dispositivos 32a y 32b de captura de imágenes en intervalos de captura de imágenes predeterminados que dependen, al menos en parte, de la velocidad de la plataforma 20.

Las señales 48a y 48b de datos de imágenes que se corresponden a cada imagen adquirida son recibidas y/o almacenadas en la memoria 82 del sistema 46 de ordenador de captura de imágenes por los puertos I/O 88. De manera similar, las señales de datos (es decir, las señales 48 de datos de imágenes, las señales 56 de localización, las señales 58 de velocidad, las señales 62 de datos de momento, las señales 64, 66 y 68 de inclinación longitudinal, balanceo y guiñada, respectivamente, la señal de rumbo 72 y la señal altitud 74) que se corresponde a cada imagen capturada son recibidas y almacenadas en la memoria 82 del sistema 46 de ordenador de captura de imágenes por los puertos I/O 88. De esta manera, la localización del dispositivo 32a y 32b de captura de imágenes en relación con la superficie 32 en el momento de preciso en el que se capturó cada imagen se registra en la memoria 82 y se asocia a la imagen capturada correspondiente.

Como mejor se muestra en la figura 1, los dispositivos 32a y 32b de captura de imágenes relativos a la tierra se corresponden al punto nadir N de la imagen ortogonal 102. De esta manera, la geolocalización exacta del punto nadir N de la imagen ortogonal 102 está indicada por las señales de localización 56, señales de velocidad 58, señales 62 de datos de tiempo, señales 64, 66 y 68 de inclinación longitudinal, balanceo y guiñada, respectivamente, señal 72 de rumbo, y señal 74 de altitud. Una vez que el punto nadir N de la imagen ortogonal 102 sea conocido, el píxel de geolocalización o cualquier otro punto o píxel en la imagen 102 es determinable de una manera conocida.

Cuando los dispositivos 32a y 32b de captura de imágenes están capturando imágenes oblicuas, tales como imágenes oblicuas 104a y 104b (figura 1), la localización de los dispositivos 32a y 32b de captura de imágenes con relación a la superficie 31 está indicada de manera similar por las señales de localización 56, señales de velocidad 58, señales 62 de datos de tiempo, señales 64, 66 y 68 de inclinación longitudinal, balanceo y guiñada, respectivamente, señal 72 de rumbo, señal 74 de altitud y el ángulo conocido de declinación θ de los ejes primarios A_1 y A_2 de los dispositivos 32a y 32b de captura de imágenes, respectivamente.

Se debe hacer notar en particular que un proceso de calibración permite que el software 90 de adquisición de imágenes y datos incorpore factores de corrección y/o corrijan cualquier error inherente o debido al dispositivo 32 de captura de imágenes, tales como, por ejemplo, errores debidos a la longitud focal calibrada, tamaño del sensor, distorsión radial, punto principal de desplazamiento y alineación.

El software 90 de adquisición de imágenes y datos crea y almacena uno más archivos 120 de salida de imágenes y datos. Más en particular, el software 90 de adquisición de imágenes y datos convierte las señales 48a y 48b de datos de imágenes y las señales de datos de orientación (es decir, señales de datos de imágenes 48, señales de localización 56, señales de velocidad 58, señales 62 de datos de tiempo, señales 64, 66 y 68 de inclinación longitudinal, balanceo y guiñada, respectivamente, señal 72 de rumbo, y señal 74 de altitud) en los archivos 120 de salida de imágenes y datos legibles por el ordenador. Como mejor se muestra en la figura 4, el archivo 120 de imágenes y datos de salida contiene una pluralidad de archivos I_1, I_2, ... I_n de imágenes capturadas que se corresponden a las imágenes oblicuas capturadas, y los datos posicionales C_{PD1}, C_{PD2}, ... C_{PDn} que se corresponden a los mismos.

Los archivos I_1, I_2, ... I_n de imágenes del archivo 120 de imágenes y datos se almacena virtualmente en cualquier formato de archivo de imágenes o gráficos legible por ordenador, tales como, por ejemplo, formatos de archivos JPEG, TIFF, GIF, BMP o PDF, y tienen una referencia cruzada con los datos C_{PD1}, C_{PD2}, ... C_{PDn} que también están almacenados como datos legibles por el ordenador. Alternativamente, los datos posicionales C_{PD1}, C_{PD2}, ... C_{PDn} está incrustado en los archivos I_1, I_2, ... I_n de imágenes correspondientes de una manera conocida. A continuación, los archivos 120 de datos de imágenes son procesados, ya sea por el software 90 de adquisición de imágenes y datos o por postprocesamiento, para corregir errores, tales como, por ejemplo, errores debidos a desviaciones del trayecto de vuelo y otros errores conocidos a cualquiera de conocimiento ordinario en la técnica. A continuación, los archivos 120 de datos de imágenes están listos para utilizarse y mostrar y tomar mediciones de y entre los objetos mostrados en las imágenes capturadas, incluyendo mediciones de las alturas de tales objetos.

Haciendo referencia a continuación a la figura 5, el sistema 130 de ordenador de visualización y medida de imágenes, tal como, por ejemplo, un ordenador personal de sobremesa convencional o un terminal de ordenador móvil en un coche de policía, incluye una memoria 132, dispositivos de entrada 134a y 134b, dispositivo 136 de pantalla, y conexión de red 138. El sistema 130 de ordenador de captura de imágenes ejecuta el software 140 de visualización y análisis de imágenes que está almacenado en la memoria 132. La memoria 132 incluye, por ejemplo, memoria no volátil de solo lectura, memoria de acceso aleatorio, memoria de disco duro, tarjetas de memoria retirables y/o otros dispositivos y/o medios de almacenamiento

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de memoria adecuados. Los dispositivos de entrada 134a y 134b, tales como por ejemplo, un ratón, tablero, palanca de control u otros dispositivos de entrada de este tipo, permiten la introducción de datos y la interacción de un usuario con el software 140 de visualización y análisis de imágenes que está siendo ejecutado por el sistema 130 de ordenador de visualización y medida de imágenes. El dispositivo 136 de pantalla, tal como, por ejemplo, una pantalla de cristal líquido o un tubo de rayos catódicos, muestra información al usuario del sistema 130 de ordenador de visualización y medida de imágenes. La conexión 138 de red conecta el sistema 130 de ordenador de visualización y medida de imágenes a una red (no mostrada) tal como, por ejemplo, una red de área local, una red de área amplia, Internet y/o la World Wide Web.

En uso, y haciendo referencia ahora a la figura 6, el sistema 130 de ordenador de visualización y medida de imágenes que ejecuta el software 140 de visualización y análisis de imágenes, accede a uno o más archivos 120 de salida de imágenes y datos que han sido leídos en la memoria 132, tal como, por ejemplo, por medio de la conexión 138 de red, controlador de disco floppy, tarjeta de memoria retirable y otros medios adecuados. A continuación, una o más de las imágenes capturadas I_1, I_2, ... I_n de los archivos 120 de salida de imágenes y datos se muestra como una imagen oblicua mostrada 142 bajo el control del software 140 de visualización y análisis de imágenes. Aproximadamente en el mismo momento, una o más porciones de datos C_{PID1}, C_{PID2}, ..., C_{PIDn} que se corresponden a la imagen oblicua mostrada 142 son leídos en la porción fácilmente accesible de la memoria 132.

Se debe hacer notar en particular que la imagen oblicua mostrada 142 se muestra sustancialmente como se captura, es decir, la imagen mostrada 142 no está deformada o ajustada en cualquier sistema coordenado, ni está ortorectificada la imagen 142. En lugar de deformar la imagen mostrada 142 en un sistema de coordenadas con el fin de permitir la medición de los objetos mostrados en la misma, el software 140 de visualización y análisis de imágenes, en general, determina la geolocalización de píxeles seleccionados solamente como se necesite, o "al vuelo", referenciando porciones de datos C_{PID1}, C_{PID2}, ..., C_{PIDn} de archivos 120 de salida de imágenes y datos, y calculando la posición y/o la geolocalización de estos píxeles seleccionados utilizando una o más ecuaciones de proyección, y se describe de manera más particular en la presente memoria descriptiva y a continuación.

En general, un usuario del sistema 130 de ordenador de visualización y medida toma medidas de y entre los objetos mostrados en la imagen oblicua mostrada 142 seleccionando uno o más de los distintos modos de medición disponibles provistos en el software 140 de visualización y análisis de imágenes. El usuario selecciona el modo de medición deseado accediendo, por ejemplo, a una serie de menús desplegables o barras de herramientas M, o por ordenes del teclado. Los modos de medición proporcionados por el software 140 de visualización y análisis de imágenes incluyen, por ejemplo, un modo de distancia que permite la medición de la distancia entre dos o más puntos seleccionados, un modo de área que permite la medición del área comprendida entre varios puntos seleccionados e interconectados, un modo de altura que permite la medición de la altura entre dos o más puntos seleccionados, y un modo de elevación que permite la medición del cambio en la elevación de un punto seleccionado con relación a uno o más otros puntos seleccionados.

Después de seleccionar el modo de medición deseado, el usuario del software 140 de visualización y análisis de imágenes selecciona con uno de los dispositivos 134a y 134b de entrada, un punto de inicio o píxel de inicio 152 y un punto o píxel de finalización 154 en la imagen mostrada 142, y el software 140 de visualización y análisis de imágenes calcula y muestra automáticamente la cantidad buscada, tal como, por ejemplo, la distancia entre el píxel de inicio 152 y el píxel de finalización 154.

Cuando el usuario selecciona el píxel/punto de inicio 152, la geolocalización del punto que se corresponde a la superficie 31 es calculada por el software 140 de visualización y análisis de imágenes, que ejecuta una o más ecuaciones de proyección utilizando las porciones de datos C_{PID1}, C_{PID2}, ..., C_{PIDn} de los archivos 120 de salida de imágenes y datos que se corresponde a la imagen particular que está siendo mostrada. La longitud y la latitud del punto en la superficie 31 que se corresponde al píxel 152 son entonces mostrados por el software 140 de visualización y análisis de imágenes en las pantallas 136, tal como, por ejemplo, superponiendo la longitud y la latitud en la imagen mostrada 142 adyacente al punto/píxel seleccionado o en una caja de visualización desplegable en cualquier punto en la pantalla 136. El mismo proceso es repetido por el usuario para seleccionar el píxel/punto 154 de finalización, y por el software 140 de visualización y análisis de imágenes para la retirada y la visualización de la información de longitud y latitud.

El cálculo de la distancia entre los puntos/píxeles de inicio y finalización 152, 154, respectivamente, se realiza determinando la geolocalización de cada píxel seleccionado 152, 154 "al vuelo". Las porciones de datos C_{PID1}, C_{PID2}, ..., C_{PIDn} del archivo 120 de salida de imágenes y datos que se corresponde a la imagen mostrada se recuperan, y la geolocalización del punto sobre la superficie 31 que se corresponde a cada píxel seleccionado es entonces determinada. Las diferencias entre las geolocalizaciones correspondientes a los píxeles seleccionados determina la distancia entre los píxeles.

Como un ejemplo de cómo se determina la geolocalización de un punto o píxel dado en la imagen oblicua mostrada 142, se asumirá que la imagen mostrada 142 se corresponde a la imagen ortogonal 104a (figura 1). El usuario del software 140 de visualización y análisis de imágenes selecciona el píxel 152 que, por simplicidad, se corresponde al centro C (figura 1) de la imagen oblicua 104a. Como se muestra en la figura 1, la línea 106 se extiende a lo largo del plano horizontal G desde un punto 108 en el mismo que está directamente debajo del dispositivo 32a de captura de imágenes, al centro C del límite o borde cercano 108 de la imagen oblicua 104a. Una extensión del eje primario A_1 se cruza con el centro C. El ángulo Φ es el ángulo formado entre la línea 106 y la extensión del eje primario A_1. De esta manera, se forma un triángulo (no referenciado) que tiene vértices en el dispositivo 32a de captura de imágenes, el punto 108 y el centro C, y que tiene lados 106, la extensión del eje primario A_1 y la línea vertical (a trazos) 110 entre el punto 108 y el dispositivo 32a de captura de imágenes.

El plano de suelo G es un plano de suelo sustancialmente horizontal, llano o no inclinado (y que típicamente tendrá una elevación que refleja la elevación media del terreno) y por lo tanto el triángulo que se ha descrito más arriba incluye un ángulo recto entre el lado/línea 110 y el lado/línea 106. Puesto que el ángulo Φ y la altitud del dispositivo 32 de captura de imágenes (es decir, la longitud del lado 110) son conocidos, la hipotenusa (es decir, la longitud de la extensión del eje primario A_1) y el resto de los otros lados del triángulo rectángulo son calculados por geometría simple. Además, puesto que la posición exacta del dispositivo 32a de captura de imágenes es conocida en el momento en que se capturó la imagen correspondiente a la imagen mostrada 142, la latitud y la longitud del punto 108 también son conocidos. Conocer la longitud del lado 106, que se ha calculado como se ha descrito más arriba, permite la geolocalización exacta del píxel 154 que se corresponde al centro C de la imagen oblicua 104a que será determinada por el software 140 de visualización y análisis de imágenes. Una vez que la geolocalización del punto que se corresponde al píxel 154 sea conocida, la geolocalización de cualquier otro píxel en la imagen oblicua mostrada 142 se puede determinar utilizando las características de cámara conocidas, tales como, por ejemplo, longitud focal, tamaño de sensor y relación de aspecto, términos radiales y otros de distorsión, etc.

La distancia entre los dos o más puntos que se corresponden a dos o más píxeles seleccionados en la imagen mostrada 142 se calcula por el software 140 de visualización y análisis de imágenes determinando la diferencia entre las geolocalizaciones de los píxeles seleccionados utilizando algoritmos conocidos, tales como, por ejemplo, la formula de Gauss y/o la formula de punto de fuga que depende del modo de medición seleccionado. La medición de objetos mostrados o que aparecen en la imagen mostrada 142 es ejecutada por un procedimiento sustancialmente similar al procedimiento que se ha descrito más arriba para medir distancias entre píxeles seleccionados. Por ejemplo, las longitudes, anchuras y alturas de objetos tales como, por ejemplo, edificios, ríos, carreteras y virtualmente cualquier otra estructura geográfica o realizada por el hombre, que aparece en la imagen mostrada 142, son medidas seleccionando el modo de medición apropiado/deseado y seleccionando los píxeles de inicio y finalización.

Se debe hacer notar en particular que en el modo de medición de distancias del software 140 de visualización y análisis de imágenes, la distancia entre los puntos/píxeles de inicio y finalización 152, 154, respectivamente, se puede determinar a lo largo de virtualmente cualquier trayecto, tal como, por ejemplo, un trayecto P1 de "línea recta" o un trayecto P2 que incluye la selección de puntos/píxeles intermedios y uno o más segmentos de "línea recta" interconectados entre los mismos.

Se debe hacer notar en particular que en el modo de medición de distancias del software 140 de visualización y análisis de imágenes determina la distancia entre píxeles seleccionados de acuerdo con el procedimiento "caminar por la tierra". El procedimiento "caminar por la tierra" crea una serie de segmentos de línea interconectados, representados colectivamente por los trayectos P1 y P2, que se extienden entre los píxeles/puntos seleccionados y que se disponen o se conforman a las caras planas de una serie de facetas interconectadas que definen un plano de suelo teselado. El plano de suelo teselado, como será descrito más en particular en la presente memoria descriptiva y a continuación, sigue o recrea ajustadamente el terreno de la superficie 31, y por lo tanto los trayectos P1 y P2 también siguen ajustadamente el terreno de la superficie 31. Midiendo la distancia a lo largo del terreno simulado por el plano de terreno teselado, el procedimiento "caminar por la tierra" proporciona una medición más precisa y útil de la distancia entre puntos seleccionados que el enfoque convencional, que deforma la imagen sobre una tierra plana o sistema plano de elevación medio, y mide la distancia entre puntos seleccionados a lo largo de la tierra plana o plano y sustancialmente ignora las variaciones en el terreno entre los puntos.

Por ejemplo, un contratista que prepara una licitación de un contrato para pavimentar una carretera sobre terreno montañoso desigual, puede determinar la cantidad aproximada de área de la carretera incluida utilizando el software 140 de visualización y análisis de imágenes y el procedimiento de medición "caminar por la tierra" provisto de esta manera. El contratista puede obtener la cantidad o área aproximada de carretera en su propia oficina, sin tener que enviar un equipo de investigación al lugar para obtener las mediciones necesarias.

Como contraste al procedimiento "caminar por la tierra" proporcionado por la presente invención, los enfoques de cálculo de "tierra plana" o distancia de altura media incluyen imprecisiones inherentes cuando se miden distancias entre puntos y/o objetos dispuestos en un terreno desigual o cuando se miden los tamaños y/o alturas de objetos dispuestos de manera similar. Incluso una inclinación o cuesta modesta en la superficie que está siendo capturada produce una diferencia en la elevación del punto nadir relativa a virtualmente cualquier otro punto de interés en la urisma. De esta manera, haciendo referencia de nuevo a la figura 1, el triángulo formado por la línea 106, la extensión del eje primario A_1 y la línea vertical (a trazos) 110 entre el punto 108 y el dispositivo 32a de captura de imágenes puede no ser un triángulo recto. En este caso, cualquier cálculo geométrico que asuma que el triángulo es un triángulo recto contendrá errores, y tales cálculos deben ser reducidos a aproximaciones, debido a incluso ligeros gradientes o pendientes entre los puntos de interés.

Por ejemplo, si la superficie 31 se inclina hacia arriba entre el punto nadir N y el centro C cerca o en el borde inferior 108 de la imagen oblicua 104, entonces la segunda línea 110 se cruza con la superficie 31 antes del punto en el cual se debería producir tal intersección en una superficie 31 a nivel o no inclinada. Si el centro C es 4,57 m más alto que el punto nadir N y con ángulo de declinación θ igual a 40° (cuarenta grados), la localización calculada del centro C estará desplazada aproximadamente 5,42 m sin corrección del cambio en elevación entre los puntos.

Como se ha discutido en general más arriba, con el fin de compensar, al menos en parte, los cambios en elevación y las imprecisiones resultantes en la medición de y entre los objetos en la imagen 142, el software 140 de visualización y análisis de imágenes referencia, cuando sea necesario, puntos en la imagen mostrada 142 y en la superficie 31 con un plano de suelo teselado o en facetas designado en general como 160 en la figura 6. El plano de suelo teselado 160

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incluye una pluralidad de facetas individuales 162a, 162b, 162c, etc., cada una de las cuales está interconectada a las otras y están definidas por cuatro vértices (no referenciados, pero que se muestran como puntos) que tienen alturas respectivas. Las parejas adyacentes de facetas 162a, 162b, 162c, etc., comparten dos vértices. Cada faceta 162a, 162b, 162c, etc. tiene inclinación longitudinal y pendiente respectivas. El plano de suelo teselado 160 se crea sobre la base de varios datos y fuentes, tales como, por ejemplo, mapas topográficos y/o gráficos en tramas digitales, datos de reconocimiento y varias otras fuentes.

En general, la geolocalización de un punto de interés en una imagen mostrada 142 se calcula determinando cual de las facetas 162a, 162b, 162c, etc. se corresponde a ese punto de interés. De esta manera, la localización del punto de interés se calcula sobre la base de las características, es decir, elevación, inclinación longitudinal y pendiente de las facetas 162a, 162b, 162c, etc. en lugar de hacerlo sobre la base de un plano de suelo llano o de elevación media. El error se introduce solamente en lo que se refiere a la topografía de la superficie 31 y la localización del punto de interés en el mismo que se desvía de la superficie plana de la faceta 162a, 162b, 162c, etc. en la cual se encuentra dispuesto el punto de interés. Ese error se puede reducir por medio de una interpolación bilineal de la altura del punto de interés en una faceta particular de las facetas 162a, 162b, 162c, etc. y utilizando la altura interpolada en el cálculo de localización ejecutado por el software 140 de visualización y análisis de imágenes.

Para usar plano de suelo teselado 160, el software 140 de visualización y análisis de imágenes utiliza un algoritmo modificado de trazado de rayos para encontrar la intersección del rayo proyectado por el dispositivo 32a o 32b de captura de imágenes hacia la superficie 31 y el plano de suelo teselado 160. El algoritmo determina no solamente cual de las facetas 162a, 162b, 162c, etc. es interseetada por el rayo, sino también donde se produce la intersección dentro de la faceta. Utilizando la interpolación bilineal, se puede determinar una localización de suelo bastante precisa. Para la proyección inversa, se utiliza el plano de suelo teselado 160 para encontrar el valor de la altura del suelo para introducir la localización de suelo, usando también la interpolación bilineal. A continuación se utilizan la altura y la localización para proyectarse hacia atrás por un modelo del dispositivo 32a o 32b de captura de imágenes para determinar cual de los píxeles dentro de la imagen mostrada 142 se corresponde a una localización dada.

Más en particular, y como un ejemplo, el software 140 de visualización y análisis de imágenes ejecuta y/o calcula la geolocalización del punto 164 superponiendo y/o ajustando el plano 160 de suelo teselado al menos a una porción 166, tal como, por ejemplo, una colina, de la superficie 31. Se debe hacer notar que solamente una pequeña porción del plano 160 de suelo teselado y de las facetas 162a, 162b, 162c, etc. de la misma se muestra a lo largo del perfil de la porción 166 de la superficie 131. Como se ha discutido más arriba, cada una de las facetas 162a, 162b, 162c, etc. está definida por cuatro vértices, cada uno de los cuales tiene elevaciones respectivas, y cada una de las facetas tiene inclinaciones longitudinales y pendientes respectivas. La posición específica del punto 164 sobre el plano/superficie de la faceta 162a, 162b, 162c, etc. dentro del cual se mantiene el punto 164 (o su proyección) se determina como se ha descrito más arriba.

El plano 160 de suelo teselado preferiblemente se crea fuera de la operación del sistema 130 de ordenador de visualización y medida de imágenes y del software 140 de visualización y análisis de imágenes. Por el contrario, el plano 160 de suelo teselado toma la forma de una tabla de datos relativamente simple o tabla de visión 168 almacenada en la memoria 132 del sistema 130 de ordenador de visualización y medida de imágenes y/o es accesible al mismo. Los recursos de cálculo requeridos para calcular las localizaciones de todos los vértices y facetas de un plano de suelo típico, no necesariamente tienen que residir en el sistema 130 de ordenador de visualización y medida de imágenes. De esta manera, el sistema 130 de ordenador de visualización y medida de imágenes es compatible para utilizarse con, y es ejecutable por, un ordenador personal convencional sin requerir recursos de cálculo adicionales.

El cálculo de plano 160 de suelo teselado fuera del sistema 130 de ordenador de visualización y medida de imágenes permite virtualmente que cualquier nivel de detalle se incorpore en el plano 160 de suelo teselado, es decir, el tamaño y/o el área cubierta por, o que se corresponde a, cada una de las facetas 162a, 162b, 162c, etc. puede ser tan grande o pequeño como se desee, sin incrementar significativamente el tiempo de cálculo, sin hacer más lenta la operación, sin incrementar significativamente los recursos requeridos por el sistema 130 de ordenador de visualización y medida de imágenes y/o el software 140 de visualización y análisis de imágenes. Por lo tanto, el sistema 130 de ordenador de visualización y medida puede ser un sistema de ordenador relativamente básico y sencillo.

El tamaño de las facetas 162a, 162b, 162c, etc. es uniforme en tamaño en una imagen mostrada 142 en particular. Por ejemplo, si la imagen mostrada 142 se corresponde a un área que es aproximadamente de 228,6 m de anchura en el primer plano por aproximadamente 274,32 m de profundidad, la imagen se puede descomponer en facetas que son aproximadamente de 15,24 m de lado, proporcionando por lo tanto aproximadamente quince facetas de anchura y dieciocho facetas de profundidad. Alternativamente, el tamaño de las facetas 162a, 162b, 162c, etc. es uniforme en términos del número de píxeles que están contenidos en las mismas, es decir, cada faceta tiene el mismo número de píxeles de anchura y del mismo número de píxeles de profundidad. Por lo tanto, las facetas en el primer plano de la imagen mostrada 142, donde la densidad de píxeles es la mayor, serán dimensionalmente más pequeñas que las facetas en el fondo de la imagen mostrada 142, donde la densidad de píxeles es la más baja. Puesto que es deseable tomar la mayor parte de las medidas en el primer plano de una imagen mostrada en donde la densidad en píxeles es la mayor, la creación de facetas que son uniformes en términos del número de píxeles que contienen, tiene la ventaja de proporcionar mediciones más precisas en el primer plano de la imagen mostrada 142 en relación con las facetas que son dimensionalmente uniformes.

Otra ventaja de utilizar píxeles como base para definir las dimensiones de las facetas 162a, 162b, 162c, etc. es que el cálculo de la localización (localización de píxeles respecto a localización de suelo) es relativamente simple. Un usuario opera el sistema 130 de ordenador de visualización y medida de imágenes pa-

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ra seleccionar un píxel dentro de una faceta dada, el software 140 de visualización y análisis de imágenes busca los datos de la faceta que se corresponde al píxel seleccionado, se calcula la elevación del píxel seleccionado como se ha discutido más arriba, y esa elevación se utiliza en el calculo de localización.

En general, el procedimiento de capturar imágenes oblicuas de la presente invención divide un área de interés, tal como, por ejemplo, una comarca, en sectores de tamaño generalmente uniforme, tales como, por ejemplo, sectores que son aproximadamente de 2,59 kilómetros cuadrados de área. Esto se realiza para facilitar la creación de un plan de vuelo para capturar imágenes oblicuas que cubran cada centímetro del área de interés, y organizar y nombrar los sectores y/o imágenes de la misma para una referencia, almacenamiento y recuperación fáciles (un proceso conocido en la técnica como "sectorización"). Debido a que los bordes de cualquier área geográfica de interés, tal como una comarca, raramente se encuentran en límites iguales de kilómetros cuadrados, el procedimiento de captura de imágenes oblicuas de la presente invención proporciona más sectores que kilómetros cuadrados en el área de interés, dependiendo en gran medida cuantos más de la longitud de los límites de la comarca así como de cómo son de rectos o dentado. Típicamente, se puede esperar un sector extra por cada dos o tres kilómetro de límite. De esta manera, si una comarca u otra área de interés es de aproximadamente 32,187 kilómetros por 56,327 kilómetros, o 1.813 kilómetros cuadrados, el área se medirá en, aproximadamente, 740 a 780 sectores.

El procedimiento de captura de imágenes oblicuas de la presente invención en general captura las imágenes oblicuas en, al menos, dos direcciones de brújula, y proporciona una cobertura total del área de interés en, al menos, esas dos direcciones de brújula. Haciendo referencia a continuación a las figuras 7 y 8, se muestra una primera realización de un procedimiento para capturar imágenes oblicuas de la presente invención. Con el fin de la claridad, las figuras 7 y 8 se basan en un sistema que tiene solamente un dispositivo de captura de imágenes. Sin embargo, se debe entender que se puede utilizar dos o más dispositivos de captura de imágenes.

El dispositivo de captura de imágenes captura una o más imágenes oblicuas durante cada paso sobre el área 200. El dispositivo de captura de imágenes, como se ha discutido más arriba, está apuntado con un cierto ángulo sobre el área 200 para capturar imágenes oblicuas de la misma. El área 200 es atravesada con un patrón hacia detrás y hacia delante, similar a la manera en que se corta el césped, por el dispositivo de transporte de imágenes y/o la plataforma, para asegurar doble cobertura del área 200.

Más en particular, el área 200 es atravesada por el dispositivo 32 de soporte de imágenes y/o la plataforma 20 siguiendo una primera trayectoria 202 para capturar de esta manera imágenes oblicuas de las porciones 202 a, 202b y 202c del área 200. A continuación, el área 200 es atravesada por el dispositivo 32 de transporte de imágenes y/o la plataforma 20 siguiendo una segunda trayectoria 204 que es paralela y está separada y en una dirección opuesta a la primera trayectoria 202, es decir 180° (ciento ochenta grados) para capturar de esta manera imágenes oblicuas de las porciones 204 a, 204b, 204c del área 200. Comparando las figuras 7 y 8, se ve que una porción 207 (figura 8) del área 200 está cubierta por las imágenes 202a-c capturadas desde una primera dirección o perspectiva, y por las imágenes 204a-c capturadas desde una segunda dirección o perspectiva. De esta manera, la porción media del área 200 es cubierta doblemente un 100% (cien por cien). El patrón que se ha descrito más arriba de atravesar o pasar sobre el área 200 a lo largo de trayectorias opuestas que son paralelas a las trayectorias 202 y 204 se repiten hasta que toda el área 200 sea completamente cubierta por al menos una imagen oblicua capturada desde las trayectorias que son paralelas, separadas una de las otras como sea obligado por el tamaño del área 200 en la misma dirección que las trayectorias 202 y 204, para de esta manera, cubrir doblemente un cien por cien el área 200 desde estas perspectivas/direcciones.

Si se desea, y para detalles mejorados, el área 200 es cubierta por dos trayectorias tercera y cuarta 206 y 208 adicionales opuestas y paralelas, respectivamente, que son perpendiculares a las trayectorias 202 y 204, como se muestra en las figuras 9 y 10. De esta manera, el área 200 es atravesada por el dispositivo de soporte de imágenes 32 y/o plataforma 20 siguiendo una tercera trayectoria 206 para capturar imágenes oblicuas de las porciones 206a, 206b y 206c del área 200, y a continuación es atravesada a lo largo por una cuarta trayectoria 208 que es paralela, separada y opuesta a la tercera trayectoria 206, para capturar imágenes oblicuas de las porciones 208a, 208b, 208c del área 200. Este patrón de atravesar o pasar sobre el área 200 a lo largo de trayectorias opuestas que son paralelas a las trayectorias 206 y 208 se repite de manera similar hasta que la totalidad del área 200 sea cubierta completamente por, al menos, una imagen oblicua capturada por trayectorias que son paralelas, y que están separadas por la manera obligada por el tamaño del área 200, y en la misma dirección que las trayectorias 206 y 208 para cubrir cien por cien el doble del área 200 desde estas direcciones/perspectivas.

Como se ha descrito más arriba, el dispositivo 32 de transporte de imágenes y/o la plataforma 20, atraviesa o pasa sobre el área 200 a lo largo de una trayectoria predeterminada. Sin embargo, se debe entender que el dispositivo y/o plataforma de transporte de imágenes y/o la plataforma 20 no necesariamente pasan o atraviesan directamente por encima del área 200, si no que, por el contrario, pueden pasar o atravesar un área adyacente, próxima, o incluso algo alejada del área 200 con el fin de asegurar que la porción del área 200 que está siendo capturada por imágenes cae dentro del campo de captura de imágenes del dispositivo de captura de imágenes. La trayectoria 202, como se muestra en la figura 7, es una trayectoria tal que no pasa directamente sobre el área 200 pero que todavía captura imágenes oblicuas de la misma.

La presente invención puede capturar imágenes con distintos varios niveles de resolución o distancias de las muestras de suelo. Un primer nivel de detalle, que en la presente memoria y a continuación se denominará nivel de comunidad, tiene una distancia de muestra de suelo de, por ejemplo, aproximadamente 0,61 metros por píxel. Para las imágenes ortogonales de nivel de comunidad, la distancia de muestra de suelo permanece sustancialmente constante en toda la imagen. Las imágenes ortogonales de nivel de comunidad se capturan con suficiente solapamiento para proporcionar una cobertura de pareja en estéreo. Para imágenes oblicuas de nivel de comunidad, la dis-

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tancia de muestra de suelo varía desde, por ejemplo, aproximadamente 0,30 metros por píxel en el primer plano de la imagen hasta aproximadamente 0,61 metros por píxel en el nivel medio de la imagen, y hasta aproximadamente 1,22 metros por píxel en el fondo de la imagen. Las imágenes oblicuas de nivel de comunidad son capturadas con suficiente solapamiento de manera que cada área de interés sea cubierta típicamente por, al menos, dos imágenes oblicuas desde cada dirección de brújula capturada. Se capturan aproximadamente diez imágenes oblicuas de nivel de comunidad por sector.

Un segundo nivel de detalle, que en la presente memoria descriptiva y a continuación se denominará nivel de barrio, es significativamente más detallado que las imágenes de nivel de comunidad. Las imágenes de nivel de barrio tienen una distancia de muestra de suelo de, por ejemplo, aproximadamente 15,24 cm por píxel. Para las imágenes ortogonales de nivel de barrio, la distancia de muestra de suelo permanece sustancialmente constante. Las imágenes oblicuas de nivel de barrio tiene una distancia de muestra de suelo de, por ejemplo, desde aproximadamente 10,16 cm por píxel en el primer plano de la imagen hasta aproximadamente 15,24 cm por píxel en el plano medio de la imagen y hasta aproximadamente 25,4 cm por píxel en el fondo de la imagen. Las imágenes oblicuas de nivel de barrio se capturan con suficiente solapamiento de manera que cada área de interés sea cubierta típicamente por al menos dos imágenes oblicuas en cada dirección de compás capturada, y de manera que las direcciones de brújula opuestas proporcionen un solapamiento del 100% entre sí. Aproximadamente se capturan cien (100) imágenes de área oblicua por sector.

Se debe hacer notar en particular que la captura de imágenes oblicuas de nivel de comunidad y/o de barrio en todas las cuatro direcciones de brújula asegura que cada punto en la imagen aparecerá en el primer plano o en una porción inferior de al menos una de las imágenes oblicuas capturadas, en donde la distancia de muestra de suelo sea la más baja y el detalle de la imagen sea el mayor.

En la realización que se muestra, el sistema 30 de captura de imágenes y geolocalización incluye un giroscopio, brújula y altímetro. Sin embargo, se debe entender que el sistema de captura de imágenes y geolocalización de la presente invención alternativamente puede estar configurado tal como, por ejemplo, para derivar y/o calcular la altitud, inclinación longitudinal, balanceo y guiñada, y rumbo de brújula para las señales/datos de GPS y INU, con lo cual hace innecesario un elemento o más de entre el giroscopio, brújula y altímetro.

En la realización que se muestra, los dispositivos de captura de imágenes se encuentran con un ángulo igual de declinación en relación a un plano horizontal. Sin embargo, se debe entender que los ángulos de declinación de los dispositivos de captura de imágenes no tienen que ser iguales.

En la realización que se muestra, el sistema de ordenador de captura de imágenes ejecuta el software de adquisición de imágenes y datos que emite una señal de captura de imágenes común o única a los dispositivos de captura de imágenes para, de esta manera, hacer que estos dispositivos adquieran o capturen una imagen. Sin embargo, se debe entender que la presente invención alternativamente puede estar configurada para producir que los dispositivos de captura de imágenes capturen por separado imágenes en diferentes instantes y/o en diferentes intervalos.

En la realización que se muestra, el procedimiento de la presente invención captura imágenes oblicuas para proporcionar doble cobertura de un área de interés desde trayectorias/perspectivas que son sustancialmente opuestas una de la otra, es decir, que se encuentran a 180° (ciento ochenta grados) en relación de una con la otra. Sin embargo, se debe entender que el procedimiento de la presente invención alternativamente puede estar configurado para proporcionar doble cobertura de trayectorias/perspectivas que son generalmente y/o sustancialmente perpendiculares una en relación con la otra.

Aunque la presente invención se ha descrito teniendo un diseño preferente, la invención puede ser modificada adicionalmente en la amplitud y el alcance de las reivindicaciones. Por lo tanto, esta exposición pretende incluir cualquier equivalente a las estructuras y a los elementos que se muestran en la presente memoria descriptiva. Además, esta exposición pretende incluir cualquier variación, utilización o adaptación de la presente invención que utilicen los principios generales que se muestran en la presente memoria descriptiva. Además, esta exposición pretende incluir cualquier diferencia con el asunto del sujeto que se muestra que se encuentre dentro de la práctica conocida o normal en la técnica pertinente y que se encuentre dentro de los límites de las reivindicaciones adjuntas.

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REIVINDICACIONES

1. Un sistema computerizado para mostrar, geolocalizar y realizar mediciones basadas en imágenes oblicuas capturadas, que comprende:

un sistema (130) de ordenador que tiene una memoria (132):

un archivo (120) de imágenes y datos accesible por el citado sistema (130) y que incluye una pluralidad de archivos de imágenes que se corresponden a una pluralidad de imágenes oblicuas capturadas, incluyendo adicionalmente el citado archivo (120) de imágenes y datos, datos de posición que se corresponden a la citada pluralidad de archivos de imágenes; y

software (140) de visualización y análisis de imágenes ejecutado por el citado sistema (130) para leer el citado archivo (120) de imágenes y datos y mostrar al menos una porción de las imágenes oblicuas capturadas como una imagen oblicua mostrada, calculando el citado software (140) de visualización y análisis de imágenes las geolocalizaciones de dos o más puntos localizados en la citada imagen oblicua mostrada, en base, al menos en parte, a los citados datos posicionales, calculando el citado software (140) de visualización y análisis de imágenes una distancia de separación entre dos o más puntos cualesquiera seleccionados en la imagen oblicua mostrada;

que se **caracteriza** por

un archivo de datos de plano de suelo que presenta un plano (160) de suelo teselado, proporcionando datos el citado archivo de datos de plano de suelo al citado software (140) de visualización y análisis de imágenes, representando el archivo de datos de plano de suelo un plano de suelo teselado que se aproxima ajustadamente, al menos, a una porción del terreno mostrado en las citadas imágenes oblicuas capturadas, comprendiendo además el citado plano de suelo teselado una pluralidad de imágenes interconectadas, comprendiendo además el citado plano de suelo teselado una pluralidad de facetas interconectadas (162a, 162b, 162c, ...) teniendo cada una de la citada pluralidad de facetas una inclinación longitudinal y una pendiente respectivas, comprendiendo el citado archivo de datos de plano de suelo una pluralidad de vértices, teniendo cada uno de la citada pluralidad de vértices elevaciones respectivas y definiendo esquinas de la citada pluralidad de facetas interconectadas (162a, 162b, 162c, ...) estando compartidos dos de la citada pluralidad de vértices por cada una de las citadas facetas interconectadas; e

identificando el citado software (140) de visualización y análisis de imágenes cual de la citada pluralidad de facetas se corresponde a un punto seleccionado en la citada imagen oblicua mostrada, y calculando una elevación del citado punto seleccionado que depende, al menos en parte, de la elevación de los vértices de la faceta que se corresponde al punto seleccionado, utilizando el citado software (140) de visualización y análisis de imágenes la citada elevación calculada para calcular la citada distancia de separación entre el citado punto seleccionado y uno o más puntos seleccionados adicionales.

2. El sistema de la reivindicación 1, en el que

el citado software (140) de visualización y análisis de imágenes calcula las citadas geolocalizaciones solamente como se precise.

3. El sistema de las reivindicaciones 1 ó 2, en el que el citado software (140) de visualización y análisis de imágenes calcula una altura de un objeto dentro de la citada imagen oblicua mostrada calculando la distancia de separación entre dos o más puntos seleccionados.

4. El sistema de una de las reivindicaciones 1 a 3, en el que el citado plano de suelo teselado (160) se encuentra superimpuesto sobre la citada imagen oblicua mostrada y que se ajusta a la misma.

5. El sistema de una de las reivindicaciones 1 a 4, en el que el citado software (140) de visualización y análisis de imágenes incluye modos de medida seleccionables por el usuario que son accesibles por medio de al menos un menú desplegable, barras de herramientas y órdenes de teclado.

6. El sistema de una de las reivindicaciones 1 a 5, en el que cada una de las citadas imágenes fue capturada por un dispositivo (32a, 32b) de captura de imágenes y en un suceso de captura de imágenes respectivo, incluyendo el citado archivo de datos posicionales de la citada imágenes y datos:

datos de tiempo que representan el momento de cada suceso de captura de imágenes;

datos de localización que representan la localización del dispositivo (32a, 32b) de captura de imágenes en cada suceso de captura de imágenes;

datos de rumbo que representan el rumbo del dispositivo (32a, 32b) de captura de imágenes de cada suceso de captura de imágenes;

datos de corrección que representan factores de corrección del dispositivo (32a, 32b) de captura de imágenes; y

datos de elevación que representan una elevación media de la superficie capturada por el dispositivo (32a,32b) de captura de imágenes.

7. El sistema de la reivindicación 6, en el que los citados datos de localización incluyen la latitud, longitud y altitud del aparato (32a, 32b) de captura de imágenes en cada suceso de captura de imágenes.

8. El sistema de la reivindicación 6 ó 7, en el que los citados datos de rumbo incluyen inclinación longitudinal, balanceo, guiñada y rumbo del citado dispositivo (32a, 32b) de captura de imágenes en cada suceso de captura de imágenes.

9. El sistema de una de las reivindicaciones 6 a 8, en el que el citado dispositivo (32a, 32b) de captura de imágenes es una cámara y los citados datos de conexión incluyen, al menos, un dato de longitud focal, de tamaño de sensor, de relación de aspecto, de punto principal de desviación, distorsión, e inclinación longitudinal del píxel.

10. El sistema de una de las reivindicaciones 6 a 9, que comprende:

un dispositivo de entrada (134a, 134b) para seleccionar un punto de inicio y un punto de finalización en la imagen oblicua mostrada; y

el citado software (140) de visualización y análisis de imágenes para recuperar los datos posicionales que se corresponden al citado punto de inicio y al citado punto de finalización del citado archivo de datos; para referenciar el citado archivo de datos de plano de suelo que se corresponden al citado plano de suelo teselado que tiene una pluralidad de facetas, teniendo cada una de las citadas facetas una inclinación longitudinal y pendiente respectivas, correspondiéndose ajustadamente el citado plano de suelo teselado a un terreno de la citada imagen oblicua mostrada; para conectar los citados puntos de inicio y finalización con segmentos de línea, conformando los citados segmentos de

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línea al citado inclinación longitudinal y pendiente de las citadas facetas para seguir de esta manera el citado terreno; y para calcular la distancia lineal a lo largo de los citados segmentos de línea entre los citados puntos de inicio y finalización, con lo cual se toma en consideración la citada inclinación longitudinal y la citada pendiente de las citadas facetas.

11. El sistema de una de las reivindicaciones 1 a 10, en el que el citado software (140) de visualización y análisis de imágenes se superpone al citado plano de suelo teselado sobre la citada imagen oblicua mostrada.

12. El sistema de la reivindicación 10 u 11, que comprende:

el citado dispositivo de entrada (134a, 134b) para seleccionar uno o más puntos intermedios en la citada imagen oblicua mostrada; y

el citado software (140) de visualización y análisis de imágenes para recuperar los datos posicionales que se corresponden al citado uno o más puntos intermedio desde el citado archivo de datos; para conectar los puntos intermedios adyacentes entres sí, y conectar los citados puntos de inicio y finalización a los puntos intermedios adyacentes con segmentos de línea, conformándose los citados segmentos de línea a la citada inclinación longitudinal y pendiente en las citadas facetas para seguir de esta manera el citado terreno; y para calcular la distancia a lo largo de los citados segmentos de línea entre los citados puntos de inicio y finalización.

13. El sistema de una de las reivindicaciones 1 a 12, en el que la citada pluralidad de facetas (162a, 162b, 162c, ...) se corresponde, cada una de ellas, a áreas iguales de la citada imagen oblicua mostrada.

14. El sistema de una de las reivindicaciones 1 a 13, en el que la citada pluralidad de facetas (162a, 162b, 162c, ...) incluyen cada una de ellas un número igual de píxeles de la citada imagen oblicua mostrada.

15. El sistema de una de las reivindicaciones 1 a 14, que comprende un dispositivo de entrada (134a, 134b) para seleccionar uno o más puntos intermedios en la citada imagen oblicua mostrada; y el citado software (140) de visualización y análisis de imágenes para recuperar los datos posicionales que se corresponden a los citados puntos intermedios.

16. El sistema de una de las reivindicaciones 1 a 15, en el que la citada distancia de separación comprende una distancia entre dos o más puntos seleccionados, una altura diferente entre uno o más puntos diferentes, una diferencia en elevación de dos o más puntos seleccionados y un área abarcada por al menos tres puntos.

17. El sistema de una de las reivindicaciones 1 a 16, que comprende:

un dispositivo (32a, 32b) de captura de imágenes, capturando el citado dispositivo (32a, 32b) de captura de imágenes, imágenes oblicuas en sucesos de captura de imágenes, emitiendo el citado dispositivo (32a, 32b) de captura de imágenes señales de imágenes/datos que se corresponden a las imágenes capturadas;

al menos un dispositivo de geolocalización (34....., 44), emitiendo cada uno de los citados al menos un dispositivo de geolocalización (34, ...44) al menos una señal de geolocalización siendo indicativa, al menos en parte, de una geolocalización del citado dispositivo (32a, 32b) de captura de imágenes durante cada suceso de captura de imágenes; y

un sistema (46) de ordenador que recibe y almacena las citadas señales de datos de imágenes y la citada al menos una señal de geolocalización; y

software (90) de adquisición de imágenes y datos que lee las citadas imágenes - datos y la citada al menos una señal de geolocalización, asociando el citado software (90) cada una de las citadas señales de imágenes - datos a la correspondiente citada al menos una señal de geolocalización de cada suceso de captura de imágenes.

18. El sistema de la reivindicación 17, en la que el citado al menos un dispositivo de geolocalización y la citada al menos una señal de geolocalización respectivamente, comprende, al menos, uno de entre los siguientes elementos:

un reloj (38) que emite al citado sistema (46) de ordenador de captura de imágenes señales de datos de los momento indicadores de un momento de cada citado suceso de captura de imágenes;

un receptor (34) de sistema global de posicionamiento (GPS) que recibe señales GPS y emite al citado sistema (46) de ordenador de captura de imágenes señales de datos de localización indicativas de una longitud y latitud del citado dispositivo (32a, 32b) de captura de imágenes, en cada uno de los citados sucesos de captura de imágenes;

una unidad (36) de navegación inercial que proporciona al citado sistema (46) de ordenador de captura de imágenes, señales de datos de velocidad indicativas de la velocidad del citado dispositivo (32a, 32b) de captura de imágenes en cada uno de los citados sucesos de captura de imágenes;

un giroscopio (40) que proporciona al citado sistema (46) de ordenador de captura de imágenes una señal de inclinación longitudinal, una señal de balanceo y una señal de guiñada que son indicativas, respectivamente, de la inclinación longitudinal, balanceo y guiñada del citado dispositivo (32a, 32b) de captura de imágenes en cada uno de los citados sucesos de captura de imágenes;

una brújula (42) que proporciona al citado sistema (46) de ordenador de captura de imágenes señales de datos de rumbo indicativas del rumbo del citado dispositivo (32a, 32b) de captura de imágenes en cada uno de los citados eventos de captura de imágenes; y

un altímetro (44) que proporciona al citado sistema (46) de ordenador de captura de imágenes señales de datos de altitud indicativas de la altitud del citado dispositivo (32a, 32b) de captura de imágenes en cada uno de los citados sucesos de captura de imágenes.

19. El sistema de la reivindicación 17 ó 18, que comprende, además, datos de corrección indicativas de las características del citado dispositivo (32a, 32b) de captura de imágenes, incluyendo longitud focal, tamaño del sensor, distorsión radial, punto principal de desviación y alineación, utilizando el citado software (90) de adquisición de imágenes y datos los citados datos de corrección para corregir las imágenes capturadas.

20. El sistema de una de las reivindicaciones 17 a 19, que comprende, además, un archivo de datos de salida creado por el citado software (90) de adquisición de imágenes y datos, incluyendo el citado archivo de datos de salida una pluralidad de archivos de imagen y de datos posicionales que se corresponden a cada una de la citada pluralidad de archivo de imagen.

21. El sistema de una de las reivindicaciones 17 a 20, que comprende, además, una plataforma (20) que

transporta el citado dispositivo (32a, 32b) de captura de imágenes una distancia predeterminada por encima de una superficie de interés.

22. El sistema de la reivindicación 21, en el que el citado dispositivo (32a, 32b) de captura de imágenes captura imágenes oblicuas de un área de interés como las citadas imágenes oblicuas por medio de:

subdividir el área (200) de interés en una pluralidad de sectores (202a, 202b, 202c);

guiar la citada plataforma (20) a lo largo de una primera trayectoria (202) para que apunte de esta manera a uno o más sectores objetivos con el citado dispositivo (32a, 32b) de captura de imágenes;

capturar con el citado dispositivo (32a, 32b) de captura de imágenes una o más imágenes oblicuas para cubrir de esta manera la totalidad de cada uno de los citados sectores objetivos con imágenes oblicuas capturados desde una primera perspectiva;

guiar la citada plataforma (20) a lo largo de una segunda trayectoria (204) para apuntar de esta manera a los citados sectores objetivos;

capturar con el citado dispositivo (32a, 32b) de captura de imágenes una o más imágenes oblicuas para cubrir de esta manera la totalidad de cada uno de los citados sectores objetivos con imágenes oblicuas capturadas desde una segunda perspectiva;

repetir las citadas etapas de guiado y captura a lo largo de trayectorias sustancialmente paralelas y separadas de las citadas trayectorias primera y segunda (202, 204) y capturar una o más imágenes oblicuas para cubrir de esta manera la totalidad de cada una de la citada pluralidad de sectores en imágenes oblicuas capturadas desde cada una de las citadas perspectivas primera y segunda;

registrar los datos posicionales indicadores de una geolocalización en el citado dispositivo (32a, 32b) de captura de imágenes en cada suceso de captura de imágenes.

23. El sistema de la reivindicación 22, en el que la citada trayectoria (204) es sustancialmente paralela en relación y a 180° (ciento ochenta grados) respecto a la citada primera trayectoria (202).

24. El sistema de la reivindicación 23, en el que la citada segunda trayectoria (204) también está separada de la citada primera trayectoria (202).

25. El sistema de una de las reivindicaciones 22 a 24 en el que:

la citada plataforma (20) está guiada a lo largo de una tercera trayectoria (206) para apuntar de esta manera a uno o más sectores objetivos con el citado dispositivo (32a, 32b) de captura de imágenes, siendo sustancialmente perpendicular la citada tercera trayectoria (206) a las citadas primera y segundas trayectorias (202, 204);

el citado dispositivo (32a, 32b) de captura de imágenes captura una o más imágenes oblicuas para capturar de esta manera la totalidad de cada uno de los citados sectores objetivos en imágenes oblicuas capturadas desde una tercera perspectiva; en el que

la citada plataforma (20) es guiada y el citado dispositivo (32a, 32b) de captura de imágenes captura las citadas imágenes oblicuas a lo largo de trayectorias sustancialmente paralelas y separadas de la citada tercera trayectoria (306); y

el citado dispositivo (32a, 32b) de captura de imágenes captura una o más imágenes oblicuas para cubrir de esta manera la totalidad de cada una de la citada unidad de sectores en imágenes oblicuas capturadas desde la citada tercera perspectiva.

26. El sistema de la reivindicación 25, en el que

la citada plataforma (20) es guiada a lo largo de una cuarta trayectoria (208) para apuntar de esta manera a uno o más sectores objetivos con el citado dispositivo (32a, 32b) de captura de imágenes, siendo sustancialmente paralela la citada cuarta trayectoria (208) a la citada tercera trayectoria (206) y a 180° (ciento ochenta grados) respecto a la citada tercera trayectoria (206);

el citado dispositivo (32a, 32b) de captura de imágenes captura una o más imágenes oblicuas para capturar de esta manera la totalidad de cada citado sector objetivo en imágenes oblicuas capturadas desde una cuarta perspectiva; y

las citadas etapas de guiado y captura se repiten a lo largo de trayectorias sustancialmente paralelas y separadas de la citada cuarta trayectoria (208), y capturar una o más imágenes oblicuas para cubrir de esta manera la totalidad de cada uno de la citada pluralidad de sectores en imágenes oblicuas capturadas desde la citada cuarta perspectiva.

27. El sistema de la reivindicación 26, en el que la citada cuarta trayectoria (208) también está separada de la citada tercera trayectoria (206).

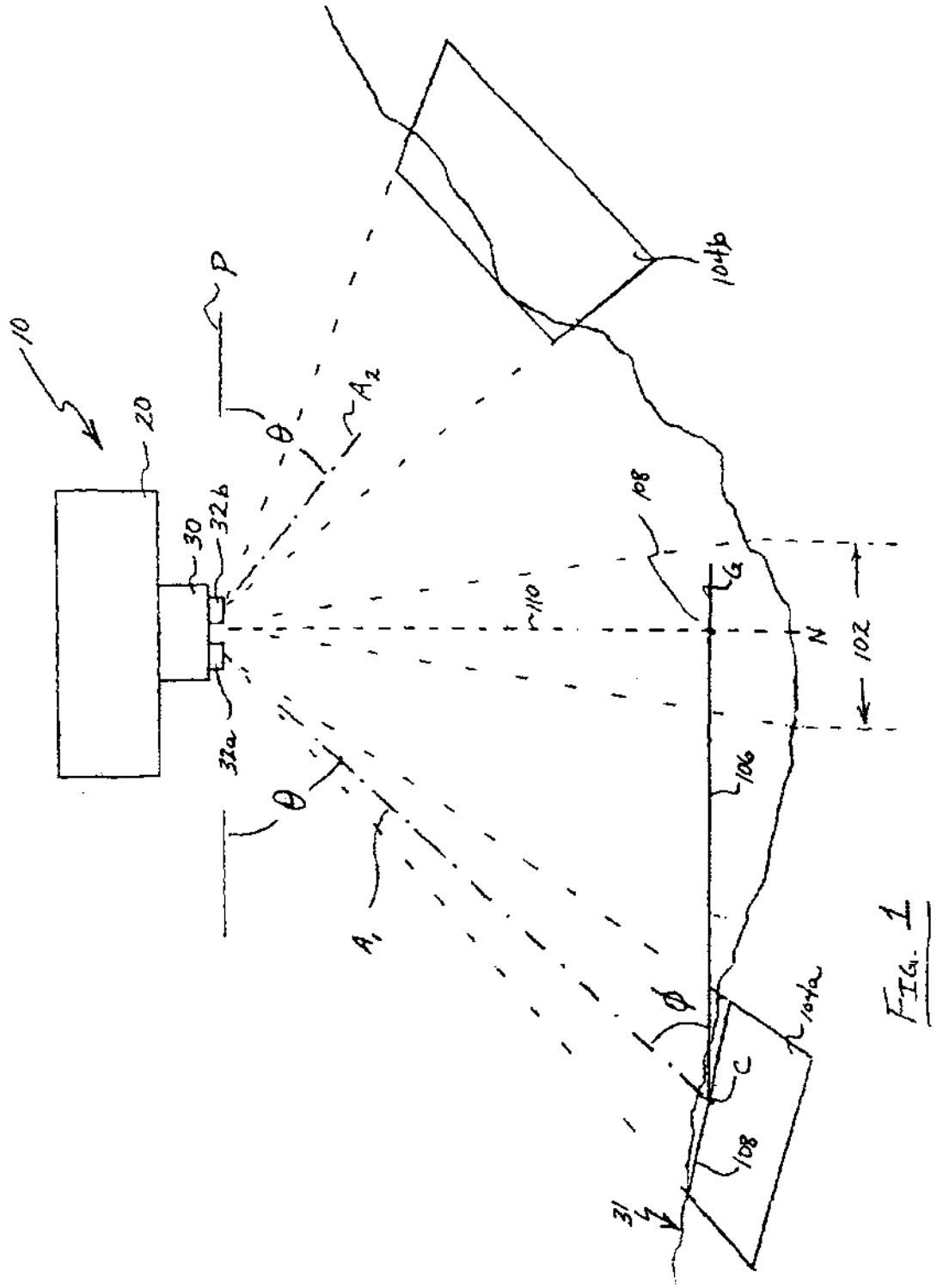


FIG. 1

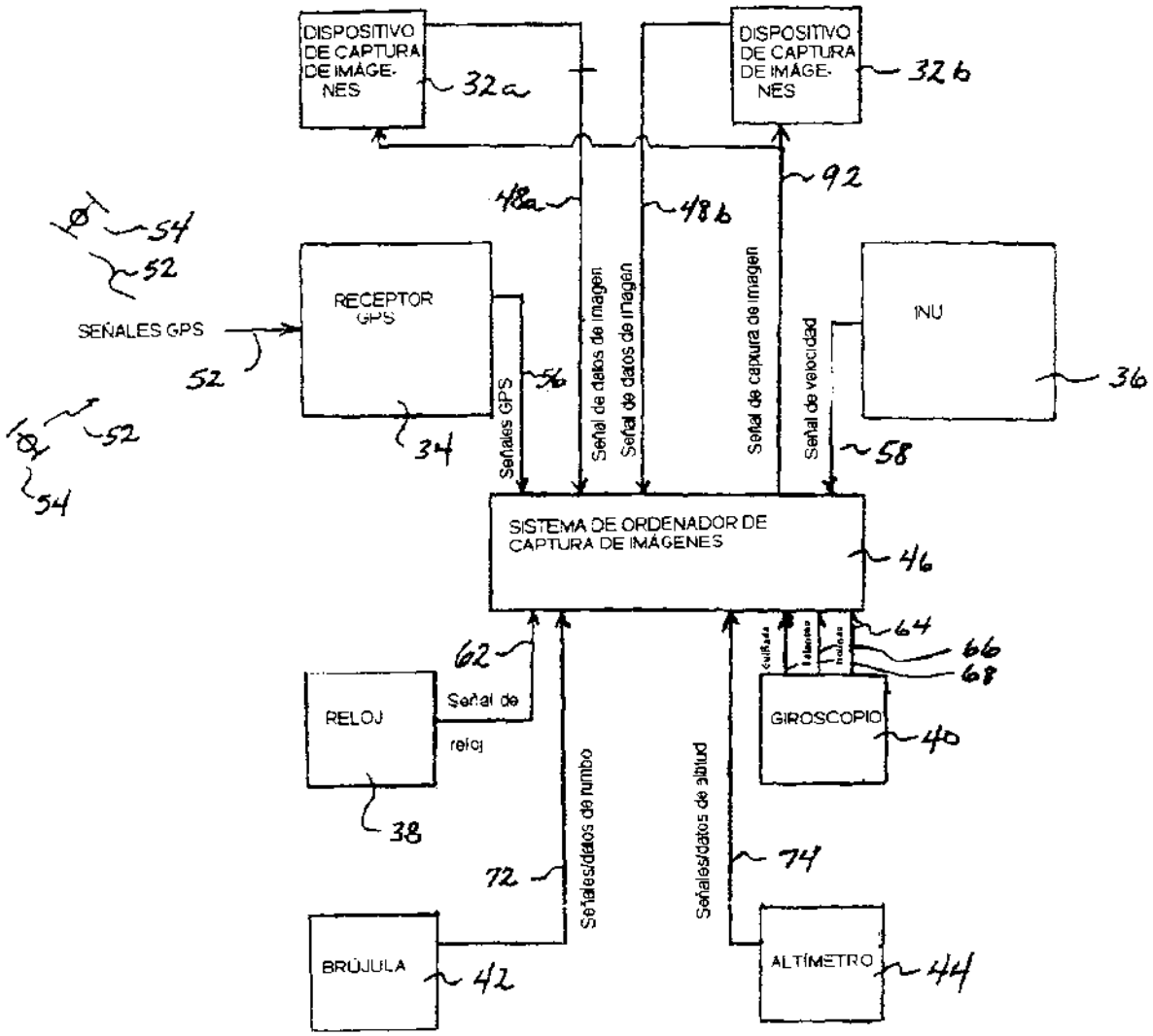

DISPOSITIVO DE CAPTURA DE IMÁGENES
32a
DISPOSITIVO DE CAPTURA DE IMÁGENES
32b
92
48a
48b
54
52
SEÑALES GPS
52
RECEPTOR GPS
34
Señales GPS
56
Señal de datos de imagen
Señal de datos de imagen
Señal de captura de imagen
Señal de velocidad
INU
36
58
SISTEMA DE ORDENADOR DE CAPTURA DE IMÁGENES
46
64
66
68
62
RELOJ
Señal de reloj
38
GIROSCOPIO
40
72
Señales/datos de rumbo
Señales/datos de altitud
74
BRÚJULA
42
ALTÍMETRO
44

FIG. 2

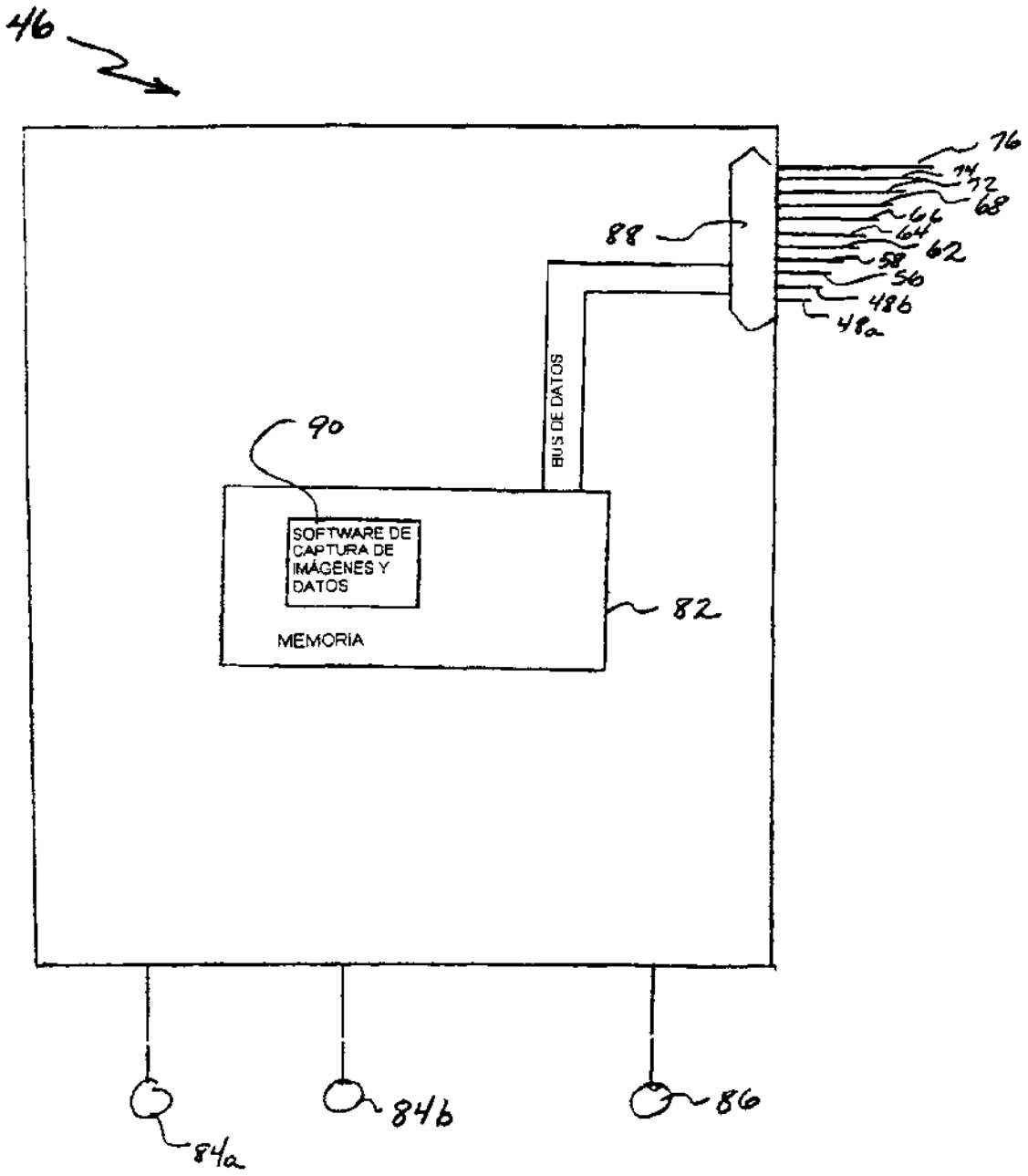

46
76
74
72
68
64
64
62
58
56
48b
48a
88
BUS DE DATOS
90
SOFTWARE DE CAPTURA DE IMÁGENES Y DATOS
MEMORIA
82
84a
84b
86

FIG. 3

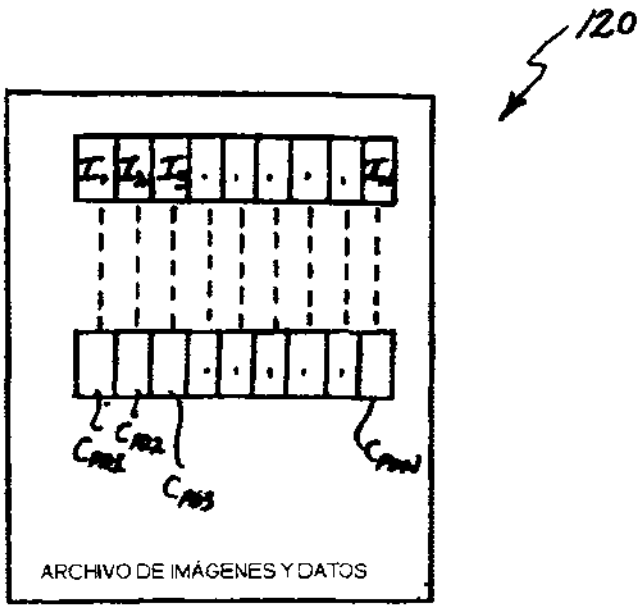


FIG. 4

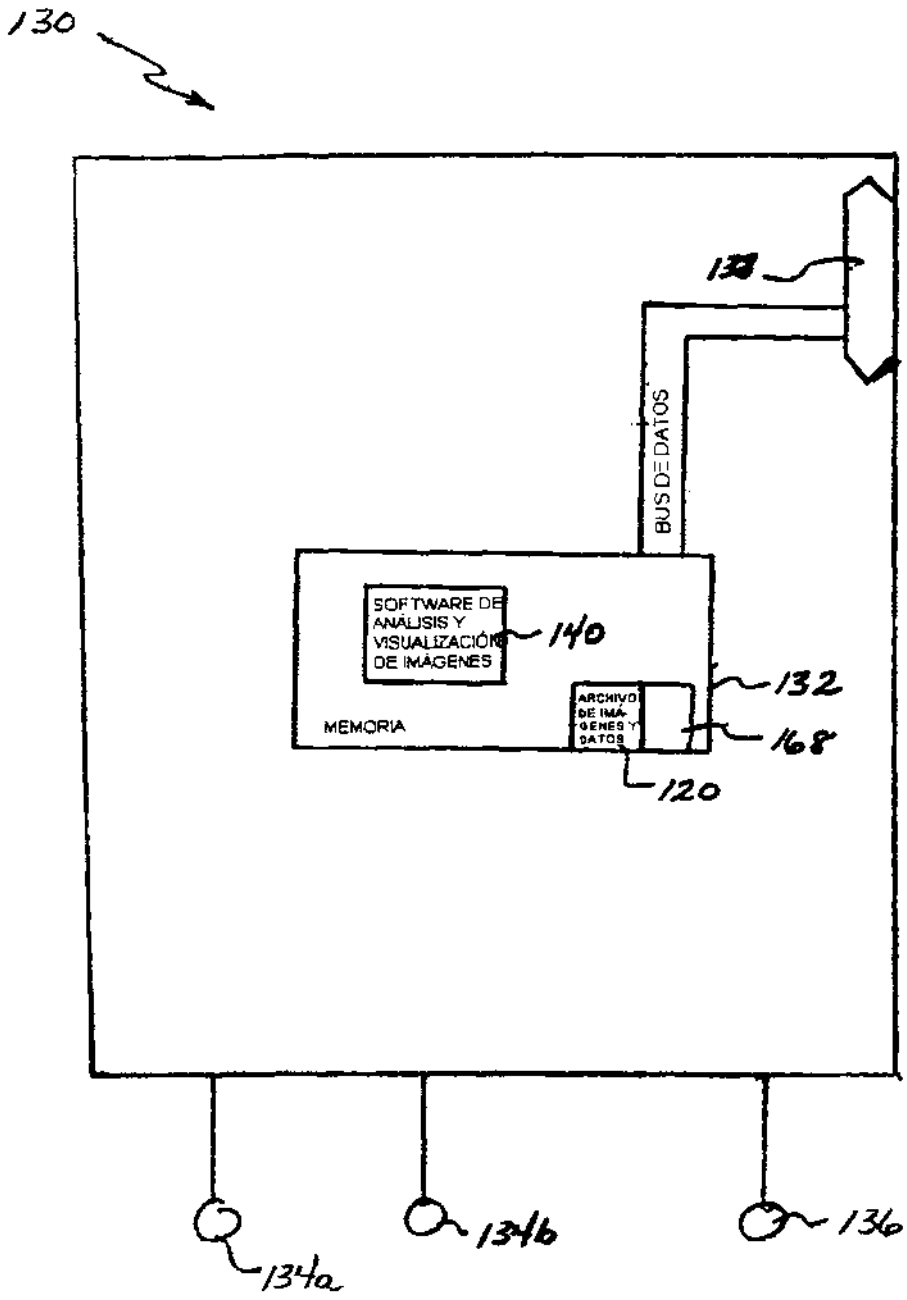

130
138
BUS DE DATOS
SOFTWARE DE ANÁLISIS Y VISUALIZACIÓN DE IMÁGENES
140
MEMORIA
ARCHIVO DE IMÁGENES Y DATOS
132
168
120
134a
134b
136

FIG. 5

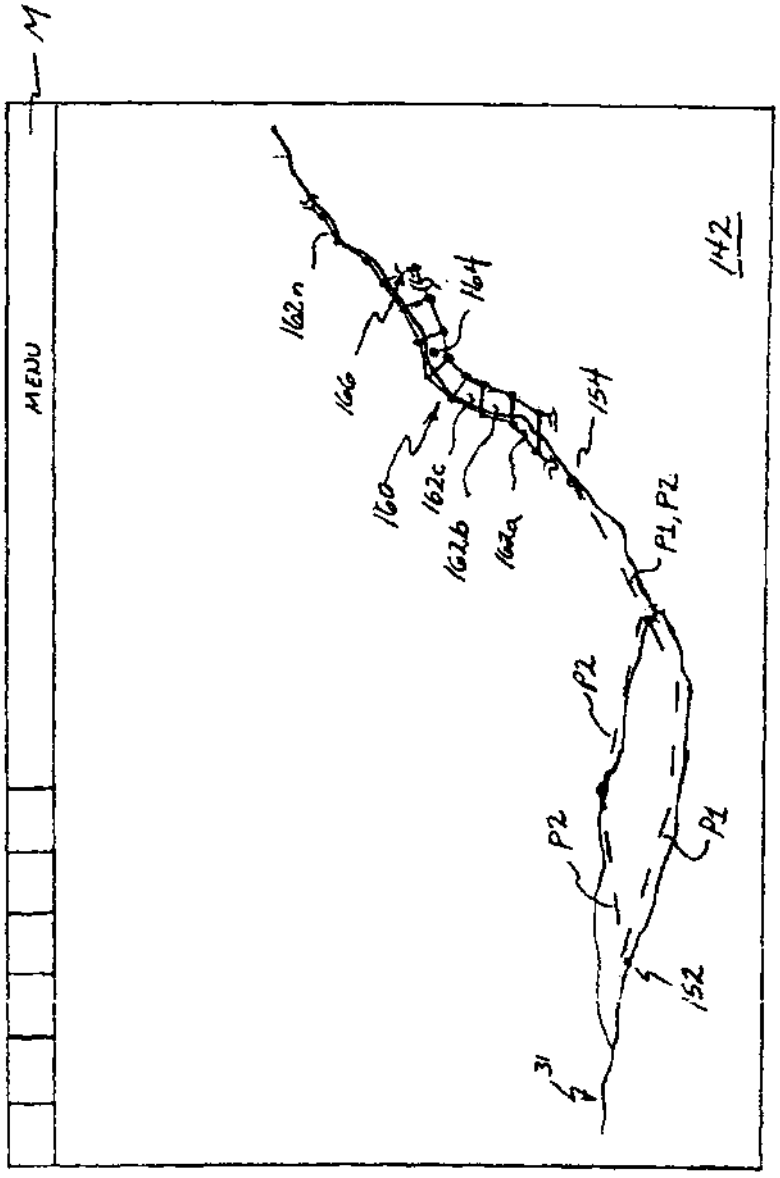

M
MENU
142
162n
164
166
154
160
162c
162b
162a
P1, P2
P2
P2
P1
152
31

FIG. 6

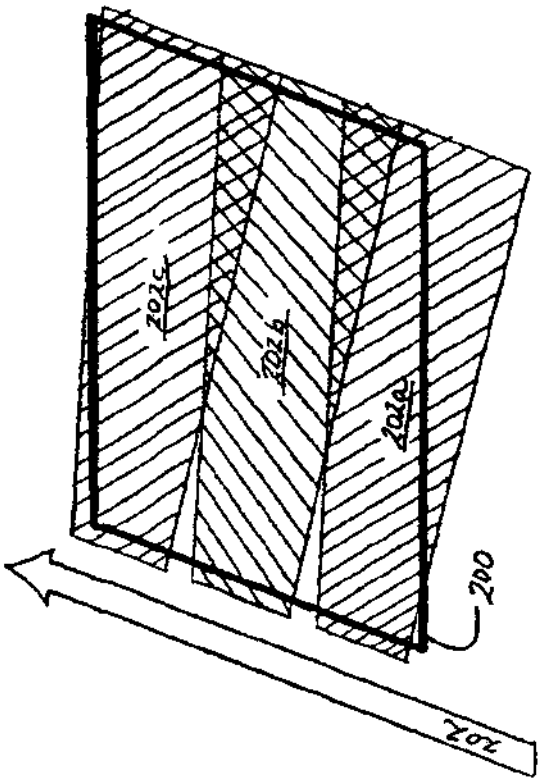


Fig. 1

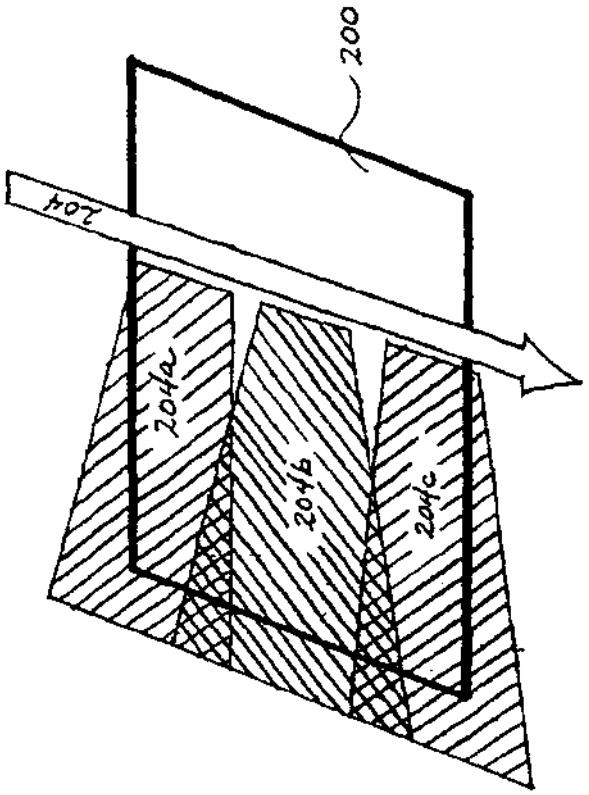


FIG. 8

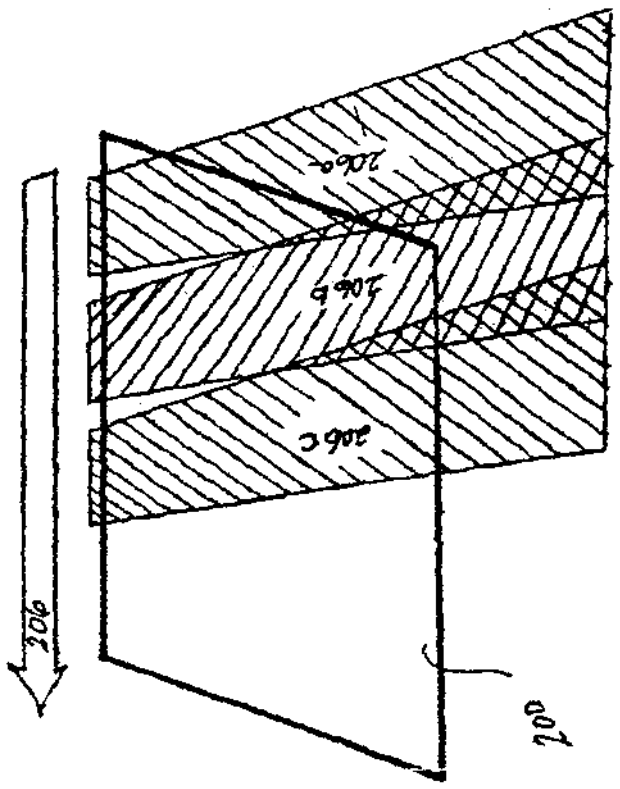


Fig 9

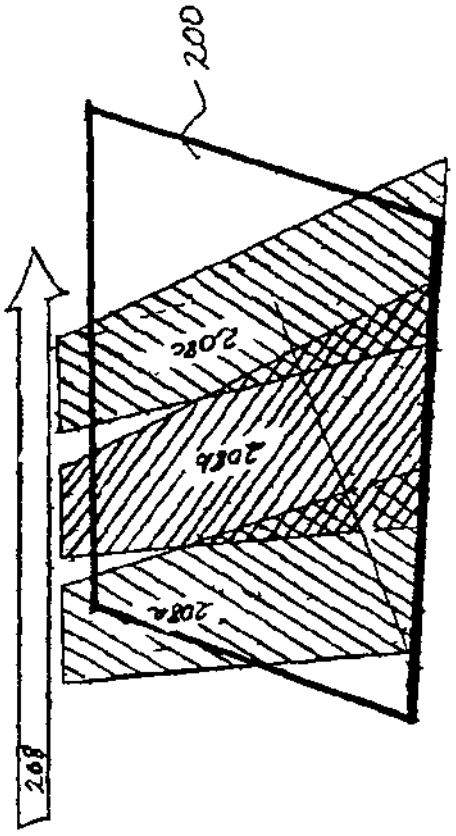


FIG. 10

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 March 2008 (06.03.2008)

PCT

(10) International Publication Number
WO 2008/028040 A2

(51) International Patent Classification:
G06K 9/00 (2006.01)

(21) International Application Number:
PCT/US2007/077242

(22) International Filing Date: 30 August 2007 (30.08.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/840,992 30 August 2006 (30.08.2006) US

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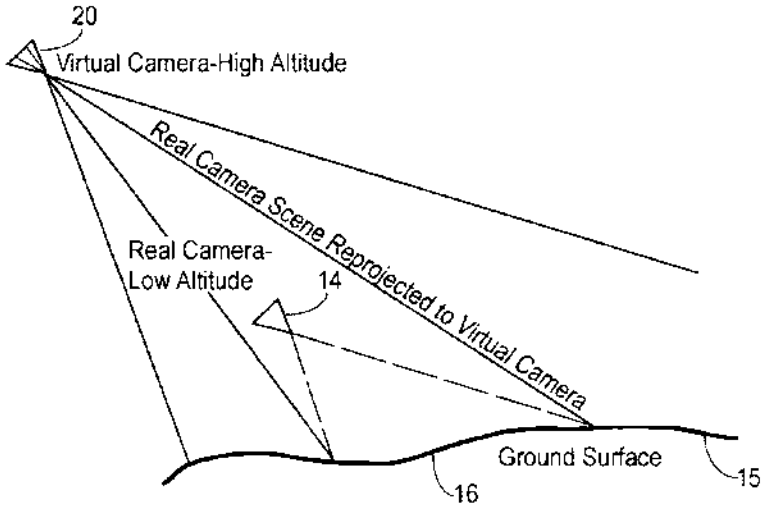
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

(54) Title: MOSAIC OBLIQUE IMAGES AND METHODS OF MAKING AND USING SAME



(57) Abstract: A method for creating an oblique-mosaic image from a plurality of source images is disclosed. Initially, a desired area to be imaged and collected into an oblique-mosaic image is identified and then a mathematical model of a sensor of a virtual camera is created, where the virtual camera has an elevation greater than an elevation of the area to be imaged. The mathematical model has an oblique-mosaic pixel map for the sensor of the desired area. A surface location is determined for each pixel included in the oblique mosaic pixel map, and at least one source oblique image pixel of the area to be imaged is reprojected for each pixel included in the oblique-mosaic pixel map to thereby create an oblique-mosaic image of the desired geographical area. The at least one single oblique-mosaic image is visually pleasing and geographically accurate. Further, techniques for compensating for building lean in oblique-mosaic images are disclosed.

WO 2008/028040 A2

MOSAIC OBLIQUE IMAGES AND METHODS OF MAKING AND USING SAME

Cross-Reference to Related Applications

[0001] The present patent application claims priority to the provisional patent application identified by U.S. Serial No. 60/840,992, the entire content of which is hereby incorporated herein by reference.

Statement Regarding Federally Sponsored Research or Development

[0002] Not Applicable.

The Names of the Parties to a Joint Research Agreement

[0003] Not Applicable.

Reference To A "Sequence Listing," A Table, Or A Computer Program Listing Appendix Submitted On A Compact Disc And An Incorporation-By-Reference Of The Material On The Compact Disc (See § 1.52(E)(5)). The Total Number Of Compact Discs Including Duplicates And The Files On Each Compact Disc Shall Be Specified

[0004] Not Applicable.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0005] The presently claimed and disclosed invention(s) relate to mosaicked oblique images and methods for making and using same. More particularly, the presently claimed and disclosed invention(s) use a methodology whereby separate obliquely captured aerial images are combined into at least one single oblique mosaic image.

The at least one single oblique-mosaic image is visually pleasing and geographically accurate.

2. Background of the Art

[0006] In the remote sensing/aerial imaging industry, imagery is used to capture views of a geographic area and be able to measure objects and structures within the images as well as to be able to determine geographic locations of points within the image. These are generally referred to as "geo-referenced images" and come in two basic categories:

1. Captured Imagery – these images have the appearance they were captured by the camera or sensor employed.

2. Projected Imagery – these images have been processed and converted such that they conform to a mathematical projection.

[0007] All imagery starts as captured imagery, but as most software cannot geo-reference captured imagery, that imagery is then reprocessed to create the projected imagery. The most common form of projected imagery is the ortho-rectified image. This process aligns the image to an orthogonal or rectilinear grid (composed of rectangles). The input image used to create an ortho-rectified image is a nadir image – that is, an image captured with the camera pointing straight down.

[0008] It is often quite desirable to combine multiple images into a larger composite image such that the image covers a larger geographic area on the ground. The most common form of this composite image is the "ortho-mosaic image" which is an image created from a series of overlapping or adjacent nadir images that are mathematically combined into a single ortho-rectified image.

[0009] Each input nadir image, as well as the output ortho-mosaic image, is composed of discrete pixels (individual picture elements) of information or data. As part of the process for creating an ortho-rectified image, and hence an ortho-mosaic image, an attempt is made to reproject (move within a mathematical model) each pixel within the image such that the resulting image appears as if every pixel in the image were a nadir pixel – that is, that the camera is directly above each pixel in the image.

[0010] The reason this ortho-rectification process is needed is it is not currently possible to capture an image where every pixel is nadir to (directly below) the camera

unless: (1) the camera used is as large as the area of capture, or (2) the camera is placed at an infinite distance above the area of capture such that the angle from the camera to the pixel is so close to straight down that it can be considered nadir. The ortho-rectification process creates an image that approximates the appearance of being captured with a camera where the area on the ground each pixel captures is considered nadir to that pixel, i.e. directly below that pixel. This process is done by creating a mathematical model of the ground, generally in a rectilinear grid (a grid formed of rectangles), and reprojecting from the individual captured camera image into this rectilinear grid. This process moves the pixels from their relative non-nadir location within the individual images to their nadir positions within the rectilinear grid, i.e. the image is warped to line up with the grid.

[0011] When creating an ortho-mosaic, this same ortho-rectification process is used, however, instead of using only a single input nadir image, a collection of overlapping or adjacent nadir images are used and they are combined to form a single composite ortho-rectified image known as an ortho-mosaic. In general, the ortho-mosaic process entails the following steps:

- A rectilinear grid is created, which results in an ortho-mosaic image where every grid pixel covers the same amount of area on the ground.

- The location of each grid pixel is determined from the mathematical definition of the grid. Generally, this means the grid is given an X and Y starting or origin location and an X and Y size for the grid pixels. Thus, the location of any pixel is simply the origin location plus the number of pixels times the size of each pixel. In mathematical terms: $X_{pixel} = X_{origin} + X_{size} \times Column_{pixel}$ and $Y_{pixel} = Y_{origin} + Y_{size} \times Row_{pixel}$.

- The available nadir images are checked to see if they cover the same point on the ground as the grid pixel being filled. If so, a mathematical formula is used to determine where that point on the ground projects up onto the camera's pixel image map and that resulting pixel value is then transferred to the grid pixel. During this selection process, two important steps are taken:

    - When selecting the image to use to provide the pixel value, a mathematical formula is used to select an image that minimizes building lean – the effect where buildings appear to lean away from the camera.

This is accomplished in a number of ways, but the most common is to pick the image where the grid pixel reprojects as close to the camera center, and hence as close to that camera's nadir point, as possible.

- When determining the source pixel value to use, the ground elevation is taken into account to ensure the correct pixel value is selected. Changes in elevation cause the apparent location of the pixel to shift when captured by the camera. A point on the ground that is higher up will appear farther from the center of the image than a point on the ground in the same location that is lower down. For instance, the top of a building will appear farther from the center of an image than the bottom of a building. By taking the ground elevation into account when determining the source pixel value, the net effect is to "flatten" the image out such that changes in pixel location due to ground elevation are removed.

[0012] Because the rectilinear grids used for the ortho-mosaic are generally the same grids used for creating maps, the ortho-mosaic images bear a striking similarity to maps and as such, are generally very easy to use from a direction and orientation standpoint. However, since they have an appearance dictated by mathematical projections instead of the normal appearance that a single camera captures and because they are captured looking straight down, this creates a view of the world to which we are not accustomed. As a result, many people have difficulty determining what it is they are looking at in the image. For instance, they might see a yellow rectangle in the image and not realize what they are looking at is the top of a school bus. Or they might have difficulty distinguishing between two commercial properties since the only thing they can see of the properties in the ortho-mosaic is their roof tops, where as most of the distinguishing properties are on the sides of the buildings. An entire profession, the photo interpreter, has arisen to address these difficulties as these individuals have years of training and experience specifically in interpreting what they are seeing in nadir or ortho-mosaic imagery.

[0013] Since an oblique image, by definition, is captured at an angle, it presents a more natural appearance because it shows the sides of objects and structures -- what we are most accustomed to seeing. In addition, because oblique images are not generally ortho-rectified, they are still in the natural appearance that the camera captures as opposed to the mathematical construction of the ortho-mosaic image. This combination makes it very easy for people to look at something in an oblique

image and realize what that object is. Photo interpretation skills are not required when working with oblique images.

[0014] Oblique images, however, present another issue. Because people have learned navigation skills on maps, the fact that oblique images are not aligned to a map grid, like ortho-mosaic images, makes them much less intuitive when attempting to navigate or determine direction on an image. When an ortho-mosaic is created, because it is created to a rectilinear grid that is generally a map grid, the top of the ortho-mosaic image is north, the right side is east, the bottom is south, and the left side is west. This is how people are generally accustomed to orienting and navigating on a map. But an oblique image can be captured from any direction and the top of the image is generally "up and back," meaning that vertical structures point towards the top of the image, but that the top of the image is also closer to the horizon. However, because the image can be captured from any direction, the horizon can be in any direction, north, south, east, west, or any point in between. If the image is captured such that the camera is pointing north, then the right side of the image is east and the left side of the image is west. However, if the image is captured such that the camera is pointing south, then the right side of the image is west and the left side of the image is east. This can cause confusion for someone trying to navigate within the image.

[0015] Additionally, because the ortho-mosaic grid is generally a rectilinear grid, by mathematical definition, the four cardinal compass directions meet at right angles (90-degrees). But with an oblique image, because it is still in the original form the camera captured and has not been reprojected into a mathematical model, it is not necessarily true that the compass directions meet at right angles within the image. Because in the oblique perspective, you are moving towards the horizon as you move up in the image, the image covers a wider area on the ground near the top of the image as compared to the area on the ground covered near the bottom of the image. If you were to paint a rectangular grid on the ground and capture it with an oblique image, the lines along the direction the camera is pointing would appear to converge in the distance and the lines across the direction of the camera is pointing would appear to be more widely spaced in the front of the image than they do in the back of the image. This is the perspective view we are all used to seeing – things are smaller in the distance than close up and parallel lines, such as railroad tracks, appear to converge in the distance. By contrast, if an ortho-mosaic image was created over this same painted rectangular grid, it would appear as a rectangular grid in the ortho-mosaic image since all perspective is removed as an incidental part of the ortho-mosaic process.

[0016] Because of these fundamental differences in perspective and appearance, the creation of an ortho-mosaic image by the process described above does not work well for oblique images. Because the camera's optical axis (an imaginary line through the center of the lens or optics that follows the aim of the camera) is typically pointed at an angle of 45-degrees or more from nadir (pointed 45-degrees or more up from straight down), the effects of building lean, elevation differences, and non-square pixels are all exaggerated – effects that are considered negative qualities in an ortho-mosaic image. In the ortho-mosaic industry, requirements are generally placed on the image capture process such that they limit the amount of obliqueness to as little as 5-degrees from nadir so as to minimize each of these negative effects.

[0017] In addition, if the admirable properties of an oblique image are to be maintained, namely seeing the sides of structures and the natural appearance of the images, then clearly a process that attempts to remove vertical displacements, and hence the sides of the buildings, and one that warps the image to fit a rectilinear grid is not a viable choice. A new process is needed, one which meets the following desirable qualities in an effort to preserve the admirable properties of the oblique image:

- If the oblique perspective is to be maintained, the pixels cannot be aligned to a rectilinear grid, or even a trapezoidal grid. Instead, the pixels are preferably aligned to the natural perspective that a camera captures.

- As part of the oblique perspective, the pixels in the image cannot all measure the same size on the ground, as pixels in the foreground of the image cover a much smaller area on the ground than pixels in the background of the image – that is by definition part of the natural perspective of a camera.

- Because the pixels are so far from nadir, the effects of building lean become extreme and the standard solutions employed in the ortho-mosaic process do not do an adequate enough job compensating for this effect – new techniques must be developed to better compensate for this effect.

- If the effects of changes in elevation are backed out, the resulting image has a very unnatural appearance – the vertical sides of buildings can warp and twist, which is something we are not accustomed to seeing and therefore, when looking at such an image, we have a tendency to "reject" it. Thus, to

keep the buildings, structures, and objects within an image looking natural, it is preferable to leave the effects of elevation in the perspective of the image and instead account for it in another manner.

[0018] Because of these issues, the common practice in the industry is to provide oblique imagery as a series of individual images. However, some of the same benefits of the ortho-mosaic also apply to an oblique-mosaic (an image created from a collection of overlapping or adjacent oblique images), namely the fact that the mosaic covers a larger geographic area than each or any of the individual images that were used to create it. This invention details a means by which a quality oblique-mosaic can be created, overcoming the above limitations.

SUMMARY OF THE INVENTION

[0019] This invention allows for the creation of an oblique-mosaic image that has both a natural appearance and is preferably geo-referenced to maintain the ability to measure and determine geographic coordinates. While the preferred embodiment applies this invention to aerial oblique imagery, the invention will also work with non-aerial oblique imagery captured in a variety of ways, including but not limited to cameras mounted obliquely on a vertical pole, hand-held cameras aimed obliquely, and cameras mounted at oblique angles on an underwater probe.

[0020] In one embodiment, the present invention is directed to a method for creating an oblique-mosaic image from a plurality of source oblique images of a geographical area. The source oblique images are preferably captured oblique images. In this method, a desired area to be imaged and collected into an oblique-mosaic image is identified, and a mathematical model of a sensor of a virtual camera is created. The virtual camera has an elevation greater than an elevation of the area to be imaged. The mathematical model has an oblique-mosaic pixel map for the sensor of the desired area. A surface location for each pixel included in the oblique mosaic pixel map is determined and/or assigned. Then, at least one source oblique image pixel of the area to be imaged is reprojected for each pixel included in the oblique-mosaic pixel map to thereby create an oblique-mosaic image of the desired geographical area. Thus, the oblique-mosaic image is a composite image formed from pixels reprojected from multiple source oblique images.

[0021] In one version of the invention, multiple source oblique images represent the same surface location. In this embodiment, the method can further comprise steps for selecting which pixels and/or source oblique images to utilize in forming the oblique-mosaic image. For example, the method can further comprise the step of selecting source oblique images of the surface location captured at an oblique angle and compass direction similar to the oblique angle and compass direction of the virtual camera. In yet another version, the pixels of each source oblique image that represent the same surface location are compared to determine which source pixel is most representative of the surface location, the more representative pixel to be included in the oblique-mosaic image.

[0022] In one version of the invention, the step of assigning is further defined by as projecting each pixel through the perspective of the virtual camera to determine a corresponding surface location for each pixel in the oblique-mosaic pixel map.

[0023] In another version of the invention, the step of reprojecting is further defined by reprojecting the pixel to match the size and shape of the represented surface location as taken from the elevation, compass direction, and oblique angle of the virtual camera.

[0024] In yet another version of the invention, the step of reprojecting is further defined by removing the effects of elevation from the source oblique images prior to reprojection and then adding the effects of elevation to the oblique-mosaic image after reprojection.

[0025] In yet another version of the invention, the method includes the step of minimizing lean of vertical structures within the oblique mosaic image. This can be accomplished in a variety of manners, such as creating an elevation model from the source oblique images taking into account the vertical structures, and reprojecting at least one source oblique image pixel of the area to be imaged utilizing the elevation model. Alternatively, lean of vertical structures can be minimized by matching vertical structures in multiple source oblique images and shifting pixels apparent location in at least one of the source oblique images by a relative height above a ground model.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0026] Fig. 1 is a schematic view of a real camera captured scene reprojected to a "virtual camera", i.e., a mathematical model that describes a camera larger than the real camera and higher in elevation than the real camera.

[0027] Fig. 2 is an illustration of an exemplary software/function flow chart of a method for making an oblique-mosaic image using a methodology whereby separate obliquely captured aerial images are combined into the oblique-mosaic image.

[0028] Fig. 3a is a pictorial representation of a prior art oblique-mosaic image.

[0029] Fig. 3b is an enlarged view of the pictorial representation of the prior art oblique-mosaic image of Fig. 3a.

[0030] Fig. 4a is a pictorial representation of an exemplary oblique-mosaic image created in accordance with the present invention.

[0031] Fig. 4b is an enlarged view of the pictorial representation of the exemplary oblique-mosaic image created in accordance with the present invention of Fig. 4a.

DETAILED DESCRIPTION OF THE PRESENTLY DISCLOSED AND CLAIMED INVENTION

[0032] Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction, experiments, exemplary data, and/or the arrangement of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein is for purpose of description and should not be regarded as limiting.

[0033] The presently claimed and disclosed invention(s) relate to oblique-mosaic images and methods for making and using the same. More particularly, the presently claimed and disclosed invention(s) use a methodology whereby separate obliquely captured aerial images are combined into at least one single oblique-mosaic image. The at least one single oblique-mosaic image is visually pleasing and geographically accurate.

[0034] Referring now to the Figures and in particular to Figs. 1 and 2, shown in Fig. 1 and designated by a reference numeral 10 is a schematic view of a method for creating an oblique mosaic image 12 (See Figures 4A and 4B). Fig. 2 is an illustration of an exemplary software/function flow chart 14 of a method for making the oblique-mosaic image 12 using a methodology whereby separate obliquely captured aerial images are combined into the oblique-mosaic image 12. Fig. 4a is a pictorial representation of an exemplary oblique-mosaic image 12 created in accordance with the present invention. Fig. 4b is an enlarged view of the pictorial representation of the exemplary oblique-mosaic image 12 created in accordance with the present invention.

[0035] In general, the method identifies a desired area 15 to be imaged and collected into the oblique-mosaic image 12. Source images are obtained utilizing a real camera 14 capturing a scene 16 as indicated by a block 18 in Fig. 2. Then, a virtual camera 20 is created as indicated by a block 22 in Fig. 2. The virtual camera 20 is a mathematical model that describes a camera larger than the real camera 14 and higher in elevation than the real camera 14 as shown in Fig. 1. The mathematical model has an oblique-mosaic pixel map for the sensor of the desired area. A surface location is assigned to each pixel included in the oblique pixel map, and then as indicated by a block 24, source oblique images are selected for the ground locations and then at least one source oblique image pixel of the area to be

imaged for each pixel included in the oblique-mosaic pixel map is reprojected to thereby create the oblique-mosaic image of the desired geographical area (as indicated by a block 26). Optionally, the method further includes one or more steps to minimize the effect of vertical structure lean as indicated by a block 28.

[0036] As described hereinabove, the use of a grid reprojection methodology to create oblique-mosaic images is fraught with problems and is unlikely to provide a useable image. Therefore, in order to produce the quality oblique-mosaic image 12, an improved process must be performed. Such an improved and unique process is described and claimed herein and preferably uses, generally, the following considerations:

- First, rather than projecting onto a rectilinear grid, the input image pixels are projected onto the "virtual camera" 20. The virtual camera 20 is a mathematical model that describes a very large camera, high up in the sky. Since it is a mathematical creation, this camera 20 is not bound by the current limitations of camera manufacturing.

- Second, the pixels are not then reprojected to be square or even the same size in the output image, as is the case in the standard ortho-rectification process used when creating an ortho-mosaic. Instead, they are reprojected to match the size they would project onto the ground from this virtual camera 20 – i.e. the natural perspective that a camera captures.

- Third, in order to best align the combined imagery, the effects of changes in elevation are first backed out of the input imagery during the projection from the original input image's camera location to the ground, and then the effects of elevation are reintroduced during the projection from the ground up to the virtual camera's location. The result is a natural looking image that properly shows the contours of the land as seen from a natural oblique perspective.

- Finally, the effects of building lean are desirably minimized. There are a number of different ways in which building lean can be minimized:

- By "steering" the cut-lines between input images down streets such that the cut-lines do not run through a building, which can cause conflicting building lean to greatly distort the appearance of a building.

- The angle of building lean can be calculated and the images warped in order to compensate for the building lean.

- The buildings can be matched in adjacent images and aligned to each other.

[0037] In practice, the methodology disclosed and claimed herein, consists of multiple steps and data transformations that can be accomplished by one of ordinary skill in the art given the present specification. There are a number of algorithms already known in the art that steer cut-lines for ortho-mosaics and could be readily adapted for use with oblique images. In addition, follow-on work could create new algorithms specifically designed to deal with the complexities of oblique images.

[0038] The first step to creating the oblique-mosaic image 12 according to the presently disclosed and claimed invention requires the selection of an area to be imaged. Generally, the area to be imaged would be a specific geographical location. However, other areas can also be selected to be imaged into the oblique-mosaic image 12 such as building sides, walls, landscapes, mountain sides and the like.

creation of a "virtual camera" 20 that is capable of covering the entire landscape or area of interest to be imaged.

[0039] Once a desired area to be imaged and collected into the oblique-mosaic image 12 has been determined, the user or operator creates the "virtual camera" 20 i.e. a mathematical construct that is capable of covering or capturing a portion of, or the entirety of the desired area. The virtual camera 20 is a mathematical model of a camera with the necessary camera geometry parameters (the mathematical values that define the camera model, for instance the number of rows and columns of the sensor plane, size of the sensor plane in millimeters, focal length in millimeters, height above ground, yaw, pitch, and roll of the optical axis) that enable it to preferably "capture" the desired scene. For instance, a virtual camera can be devised having a very large sensor (e.g. 20,000 pixel columns and 10,000 pixel rows), a standard field of view (36 mm by 24 mm sensor plane and a 60 mm focal length), and be "placed" at a relatively high altitude (e.g. 30,000 feet) looking down at

an oblique angle to the north (yaw and roll of 0 and pitch of –40 degrees). In a preferred embodiment, a sensor model from a real camera is used and the user simply modifies the parameters such that it meets the requirements in order to "capture" the desired area.

[0040] The second step creates the resulting oblique pixel map for the virtual camera 20. The pixel map corresponds to the virtual camera's sensor and thus typically, but not necessarily, has the same number of rows and columns as the virtual camera's sensor. Then, for each pixel in the pixel map image, the projective equations for the virtual camera 20 are used to project each pixel downward and away from the virtual camera 20 and onto the ground, taking elevation into account when doing so (generally through the use of a mathematical elevation model of the ground surface). This results in a corresponding ground location for that virtual camera's pixel.

[0041] Once the corresponding ground location has been found, it can be used to select which previously captured images contain image data for that ground location. This is generally done by checking to see if the ground location lies within the image boundaries of a previously captured image.

[0042] When selecting source oblique images, e.g., input captured images, in order to achieve a desirable output image, it is important to use source oblique images that were captured in the same, or nearly the same, relative orientation of the virtual camera 20, in terms of oblique downward angle and compass direction of the optical axis. While it is generally not an issue to use input imagery from a camera whose model is different than the virtual camera's model, if that model is radically different (for instance, a line scanner versus a full frame capture device), it may result in an undesirable resulting image.

[0043] While this invention discusses using captured images as input to the oblique mosaic 12, it is not actually required. It is possible to use a projected image as input to this process or even to use another oblique mosaic as input to this process. However, since this process reprojects the input images, it is desirable to use non-projected input images, i.e. captured images. The reason is that reprojecting already projected data can often lead to artifacts, sort of like rounding errors in mathematical calculations. These artifacts can create an undesirable resulting oblique-mosaic.

[0044] It is generally desirable to create the continuous oblique-mosaic 12. In order to do so, there must be captured image data for the entire area being "captured" by the virtual camera 20. This means that if multiple captured images are being combined to create the oblique-mosaic 12, those input images must be adjacent or more commonly, overlapping. As a result of this overlap, it is common for there to be multiple captured images covering the same area on the ground. If multiple captured

images are available for selection, a preferred captured image is chosen according to the selection criteria described below.

[0045] When multiple images from real cameras 14 cover the same point on the ground, a selection process can be used to determine which real camera image should be used as input for the creation of the virtual camera's pixel map image. This selection process can be done by assigning weights (assigned numerical values) to the following input criteria, multiplying those weights by the normalized criterion (a value that has been scaled between 0 and 1), and then selecting the image with the greatest sum of these weight/criterion products. While any number of criteria can be used, the following three criteria have been used in the development of this invention:

Selection Criterion: Distance to Optical Axis

[0046] The distance between the point on the ground being selected and the point where the input camera's optical axis intersects the ground. This value can be normalized by dividing the distance by the maximum distance able to be measured in the scene.

Selection Criterion: Angular Difference to Optical Axis

[0047] The difference between the following two angles: the angle of the input camera's optical axis (generally measured relative to the perpendicular) and the angle of the ray being cast from the virtual camera to the point on the ground being selected (again, generally measured relative to the perpendicular). This value can be normalized by dividing by 180-degrees.

Selection Criterion: Distance to Nearest Street Centerline

[0048] The distance between the point on the ground being selected and the nearest street centerline. The street centerlines can be obtained from vector data files such as TIGER files or other Geographic Information System files. This value can be normalized by dividing by the maximum distance able to be measured in the scene.

[0049] Once the preferred captured image has been selected, the projective equations for the captured image's camera are used to project from the ground up to the camera, taking the ground elevation into account when doing so. This projection through the focal point and onto the camera's sensor plane will find a pixel row and

column corresponding to the point on the ground. As this typically does not fall on an integer row or column, bilinear interpolation (an industry standard mathematical formula for finding a single value from the proportionate proximity to the four surrounding pixels) is used to find the pixel value for the corresponding point on the camera's sensor plane.

[0050] This pixel value is then used to fill the pixel in the image that corresponds to the virtual camera's sensor plane from which the original ray was projected outward onto the ground. This process is repeated for some or all of the remaining pixels in the virtual camera's sensor plane, resulting in an image that covers some area or the entire area on the ground that the virtual camera 20 can "see." Preferably, this process is repeated for all of the remaining pixels in the virtual camera's sensor plane, resulting in a complete image that covers the entire area on the ground that the virtual camera 20 can "see."

[0051] The resulting image and its corresponding projective equations are then stored. The resulting image can be stored in any format, including one of many industry standard image formats such as TIFF, JFIF, TARGA, Windows Bitmap File, PNG or any other industry standard format. For the corresponding projective equations, the following data should, in a preferred embodiment, be stored as metadata with the resulting image, either appended to the same file or in another file readily accessible (an industry standard practice is to use the same filename but with a different file extension):

1. The location of the camera – generally, the location of the camera is specified by a geographic location and altitude (or height over ground).

2. The orientation of the camera – generally specified by three angles: yaw, pitch and roll (or omega, phi, and kappa).

3. The size of the sensor – generally specified as an overall sensor size in millimeters (or by the size of an individual sensor element).

4. The focal length of the lens – generally specified in millimeters.

5. Optionally, lens distortion information – generally specified as a principal point offset (offset between the optical axis and the middle of the sensor) and as radial distortion terms (polynomial coefficients that describe the amount of distortion that occurs radially out from the optical axis).

6. Optionally, a ground elevation model – generally specified as a grid of elevation values.

[0052] As discussed above, the relative perspective of the camera causes an effect known as "building lean." While building lean is most commonly applied to, and thus discussed as, buildings, it also applies to any vertical structure in the object, such as electrical towers, trees, cars, phone booths, mailboxes, street signs, and so on. Building lean is an effect that makes it appear as if buildings that are not along the optical axis of the camera "lean" away from the optical axis – the farther away from the optical axis, the greater the lean. This lean is the result of perspective, which causes objects that are raised off the ground to appear farther "back" into the image, away from the camera. Thus, the top of a building appears farther back than the bottom of a building. When this lean corresponds to the camera's perspective, it looks normal. However, as part of the oblique-mosaic process, captured images, each with their own perspective, are combined into a single virtual camera's perspective.

[0053] This combination of different perspectives becomes problematic, especially when two different captured images from different vantage points contribute pixel values to adjacent areas in the virtual camera's pixel map image. For example: If a camera to the left of a building provides the left side of a building, then that portion of the building will appear to be leaning to the right (away from the camera). If a camera that is located to the right of the building provides the right side of the building, then that portion of the building will appear to be leaning to the left. Since the two halves of the building "lean into" each other, the resulting combined image has a building that has a triangular, rather than a rectangular, appearance.

[0054] Because building lean only affects surfaces above the surface of the ground, it is generally fairly difficult to account for or correct these effects because in order to do so, the user must have knowledge of the presence of the building or structure. Features that are on the ground do not experience this building lean because the change in relative perspective is backed out when ground elevation is taken into account in the projective equations. The mathematical model used to define the ground surface during the projective process ensures the correct ground location is selected. However, for objects that rise above the ground surface, and are not represented in the mathematical model used to define the ground surface, this relative perspective change causes the virtual camera to "see" the building top in the wrong place – i.e. too far back from the camera.

[0055] A method for minimizing the effects of building lean, as contemplated herein, is to transition between one input camera image and the next input camera image over an area where there are no structures above or below the ground elevation model. In one embodiment, this is accomplished by placing the transition down the middle of a street. Thus, by having a properly weighted selection criterion for distance to street centerline, if there is a street in the area where two captured images overlap, then the transition from contributing pixels from the one captured image to contributing pixels from the second captured image will occur along this street, thus minimizing the effects of building lean.

[0056] A method for removing building lean entirely, as contemplated herein, is to provide an accurate ground elevation model taking into account buildings and other vertical structures. Thus, every pixel that comprises the image of the building is represented in the mathematical model of the ground elevation model and therefore the change in relative perspective is accounted for in the projective process. However, for this to work well, the elevation model must be highly correlated to the input imagery. If there is any shift in location between the imagery and the elevation model, then the buildings will not be projected properly when creating the oblique-mosaic image 12.

[0057] To overcome this limitation, the preferred methodology is to create the elevation model from the imagery itself. This can be done by using an industry standard process known as aero-triangulation, which finds the elevation of a point on the ground by comparing its location in two overlapping captured images and using the projective equations of their corresponding cameras to triangulate its location and elevation. Repeating this process over the entire overlap area can produce an accurate mathematical model of the surface of not only the ground, but also of the surface of structures and objects within the images. More importantly, because this model is derived from the imagery itself, it is by definition, highly correlated to the input image.

[0058] Another method for removing building lean, contemplated for use herein, is to attempt to identify vertical structures by using an edge matching process between the oblique and the corresponding nadir imagery. Vertical structures do not appear in a truly nadir image, and they barely appear in a slightly off-nadir image. Thus, when comparing an oblique image with its corresponding nadir image, the primary difference between the structures that appear in the two images will be the vertical structures. By using one or more edge detection algorithms (such as an industry standard Laplacian Filter), it is possible to identify the various structures within the two images and then isolate the vertical edges in the oblique image by subtracting

out the non-vertical structures that also appear in the nadir image. Once these vertical structures have been found, the pixels for those vertical structures can be shifted to remove the effects of the change in relative perspective. By shifting the pixel's apparent location in the captured oblique image by the relative height above the ground model found through the measuring of the vertical edges, its proper ground location can be determined, thus negating the effects of building lean.

[0059] It should be understood that the processes described above can be performed with the aid of a computer system running image processing software adapted to perform the functions described above, and the resulting images and data are stored on one or more computer readable mediums. Examples of a computer readable medium include an optical storage device, a magnetic storage device, an electronic storage device or the like. The term "Computer System" as used herein means a system or systems that are able to embody and/or execute the logic of the processes described herein. The logic embodied in the form of software instructions or firmware may be executed on any appropriate hardware which may be a dedicated system or systems, or a general purpose computer system, or distributed processing computer system, all of which are well understood in the art, and a detailed description of how to make or use such computers is not deemed necessary herein. When the computer system is used to execute the logic of the processes described herein, such computer(s) and/or execution can be conducted at a same geographic location or multiple different geographic locations. Furthermore, the execution of the logic can be conducted continuously or at multiple discrete times. Further, such logic can be performed about simultaneously with the capture of the images, or thereafter or combinations thereof.

[0060] Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious to those skilled in the art that certain changes and modifications may be practiced without departing from the spirit and scope thereof, as described in this specification and as defined in the appended claims below.

What is claimed is:

1. A method for creating an oblique-mosaic image from a plurality of source oblique images, comprising the steps of:

identifying a desired area to be imaged and collected into an oblique-mosaic image;

creating a mathematical model of a sensor of a virtual camera, where the virtual camera has an elevation greater than an elevation of the area to be imaged, the mathematical model having an oblique-mosaic pixel map for the sensor of the desired area;

assigning a surface location to each pixel included in the oblique mosaic pixel map; and

reprojecting at least one source oblique image pixel of the area to be imaged for each pixel included in the oblique-mosaic pixel map to thereby create an oblique-mosaic image of the desired geographical area.

2. The method of claim 1, wherein the step of assigning is further defined by projecting each pixel through the perspective of the virtual camera to determine a corresponding surface location for each pixel in the oblique-mosaic pixel map.

3. The method of claim 1, wherein multiple source oblique images represent the same surface location.

4. The method of claim 1, wherein the method further comprises the step of selecting source oblique images of the surface location captured at an oblique angle and compass direction similar to the oblique angle and compass direction of the virtual camera.

5. The method of claim 3, wherein the pixels of each source oblique image that represent the same surface location are compared to determine which source pixel is most representative of the surface location, the more representative pixel to be included in the oblique-mosaic image.

6. The method of claim 1, wherein the step of reprojecting is further defined by reprojecting the pixel to match the size and shape of the represented surface location as taken from the elevation, compass direction, and oblique angle of the virtual camera.

7. The method of claim 1, wherein the step of reprojecting is further defined by removing the effects of elevation from the source oblique images prior to reprojection and then adding the effects of elevation to the oblique-mosaic image after reprojection.

8. The method of claim 1, further comprising the step of minimizing lean of vertical structures within the oblique mosaic image.

9. The method of claim 8, wherein the step of minimizing lean of vertical structures within the oblique mosaic image is defined further as the steps of creating an elevation model from the source oblique images taking into account the vertical structures, and reprojecting at least one source oblique image pixel of the area to be imaged.

10. The method of claim 8, wherein the step of minimizing lean of vertical structures is defined further as matching vertical structures in multiple source oblique images and shifting pixels apparent location in at least one of the source oblique images by a relative height above a ground model.

11. The method of claim 1, wherein metadata is stored with the oblique-mosaic image.

12. The method of claim 1, wherein the oblique-mosaic image is geo-referenced.

13. The method of claim 1, wherein the desired area to be imaged represents a geographical area.

14. A method for creating an oblique-mosaic image from a plurality of source oblique images, comprising the steps of:

identifying a desired area to be imaged and collected into an oblique-mosaic image;

creating a mathematical model of a sensor of a virtual camera, where the virtual camera has an elevation greater than an elevation of the area to be imaged, the mathematical model having an oblique-mosaic pixel map for the sensor of the desired area;

determining a surface location for each pixel included in the oblique mosaic pixel map; and

reprojecting at least one source oblique image pixel of the area to be imaged for each pixel included in the oblique-mosaic pixel map to thereby create an oblique-mosaic image of the desired geographical area.

15. The method of claim 14, wherein the step of determining is further defined by projecting each pixel through the perspective of the virtual camera to determine a corresponding surface location for each pixel in the oblique-mosaic pixel map.

16. The method of claim 14, wherein multiple source oblique images represent the same surface location.

17. The method of claim 14, wherein the method further comprises the step of selecting source oblique images of the surface location captured at an oblique angle and compass direction similar to the oblique angle and compass direction of the virtual camera.

18. The method of claim 16, wherein the pixels of each source oblique image that represent the same surface location are compared to determine which source pixel is most representative of the surface location, the more representative pixel to be included in the oblique-mosaic image.

19. The method of claim 14, wherein the step of reprojecting is further defined by reprojecting the pixel to match the size and shape of the represented surface location as taken from the elevation, compass direction, and oblique angle of the virtual camera.

20. The method of claim 14, wherein the step of reprojecting is further defined by removing the effects of elevation from the source oblique images prior to reprojection and then adding the effects of elevation to the oblique-mosaic image after reprojection.

21. The method of claim 14, further comprising the step of minimizing lean of vertical structures within the oblique mosaic image.

22. The method of claim 21, wherein the step of minimizing lean of vertical structures within the oblique mosaic image is defined further as the steps of creating an elevation model from the source oblique images taking into account the vertical structures, and reprojecting at least one source oblique image pixel of the area to be imaged.

23. The method of claim 21, wherein the step of minimizing lean of vertical structures is defined further as matching vertical structures in multiple source oblique images and shifting pixels apparent location in at least one of the source oblique images by a relative height above a ground model.

24. The method of claim 14, wherein metadata is stored with the oblique-mosaic image.

25. The method of claim 14, wherein the oblique-mosaic image is geo-referenced.

26. The method of claim 14, wherein the desired area to be imaged represents a geographical area.

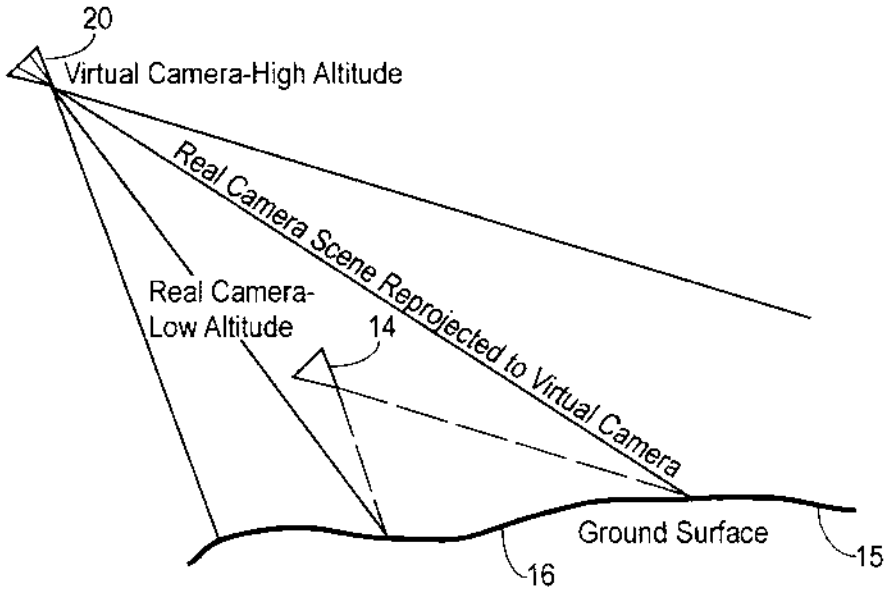

20
Virtual Camera-High Altitude
Real Camera Scene Reprojected to Virtual Camera
Real Camera-
Low Altitude
14
Ground Surface
15
16

Fig. 1

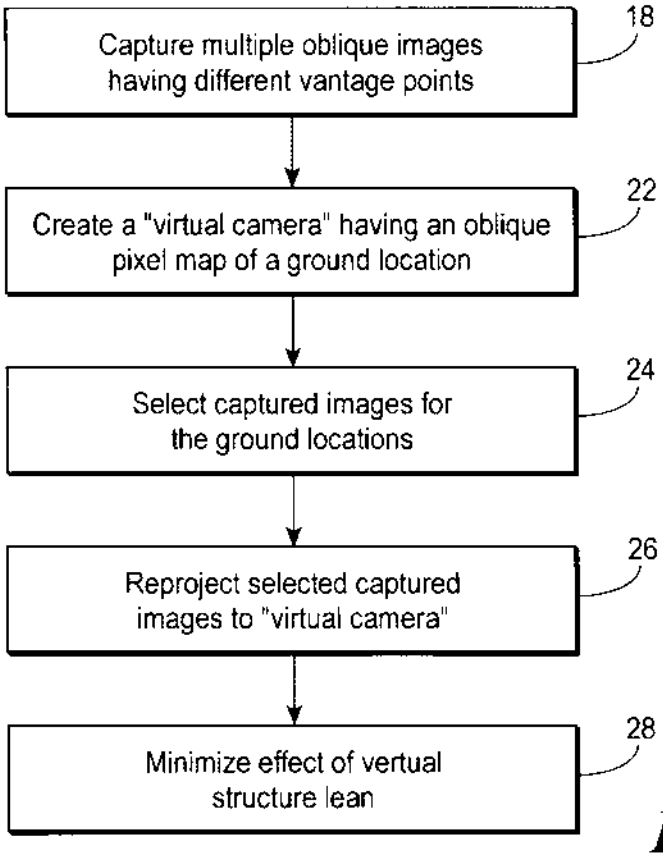
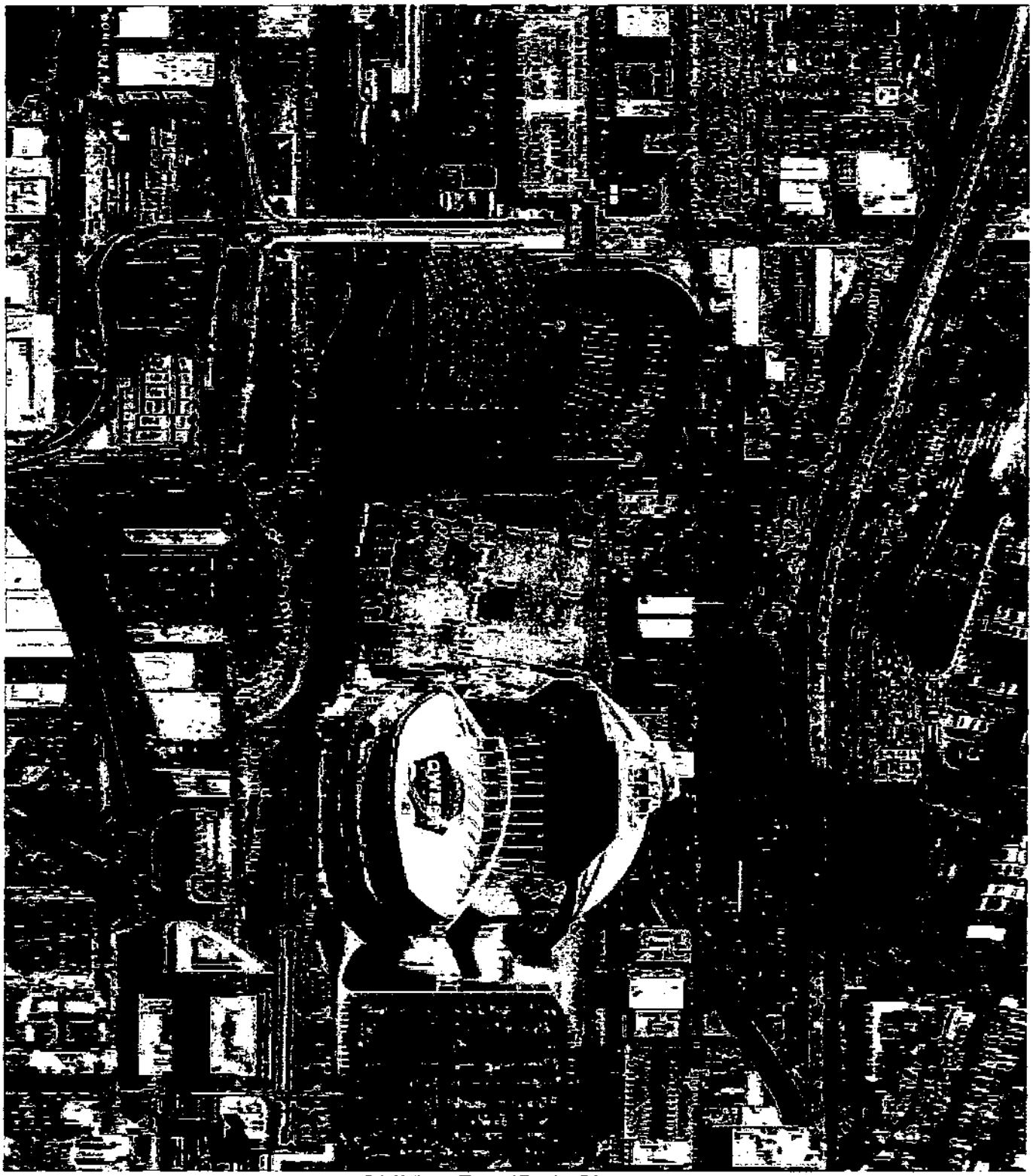

Capture multiple oblique images having different vantage points
18
Create a "virtual camera" having an oblique pixel map of a ground location
22
Select captured images for the ground locations
24
Reproject selected captured images to "virtual camera"
26
Minimize effect of vertual structure lean
28

Fig. 2



FIG. 3A



Oblique-Rectified_Closeup

FIG. 3B

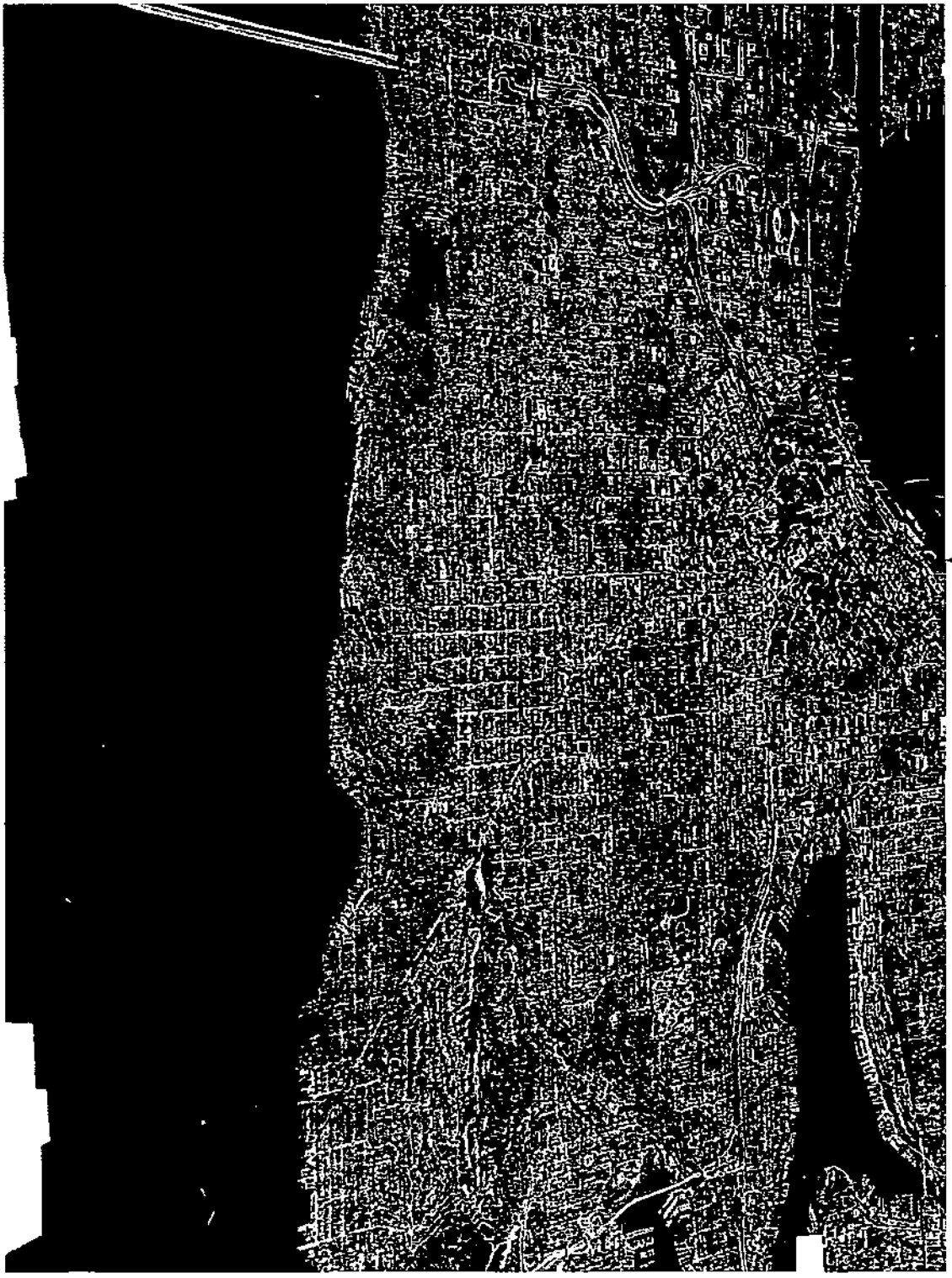


Fig. 4A

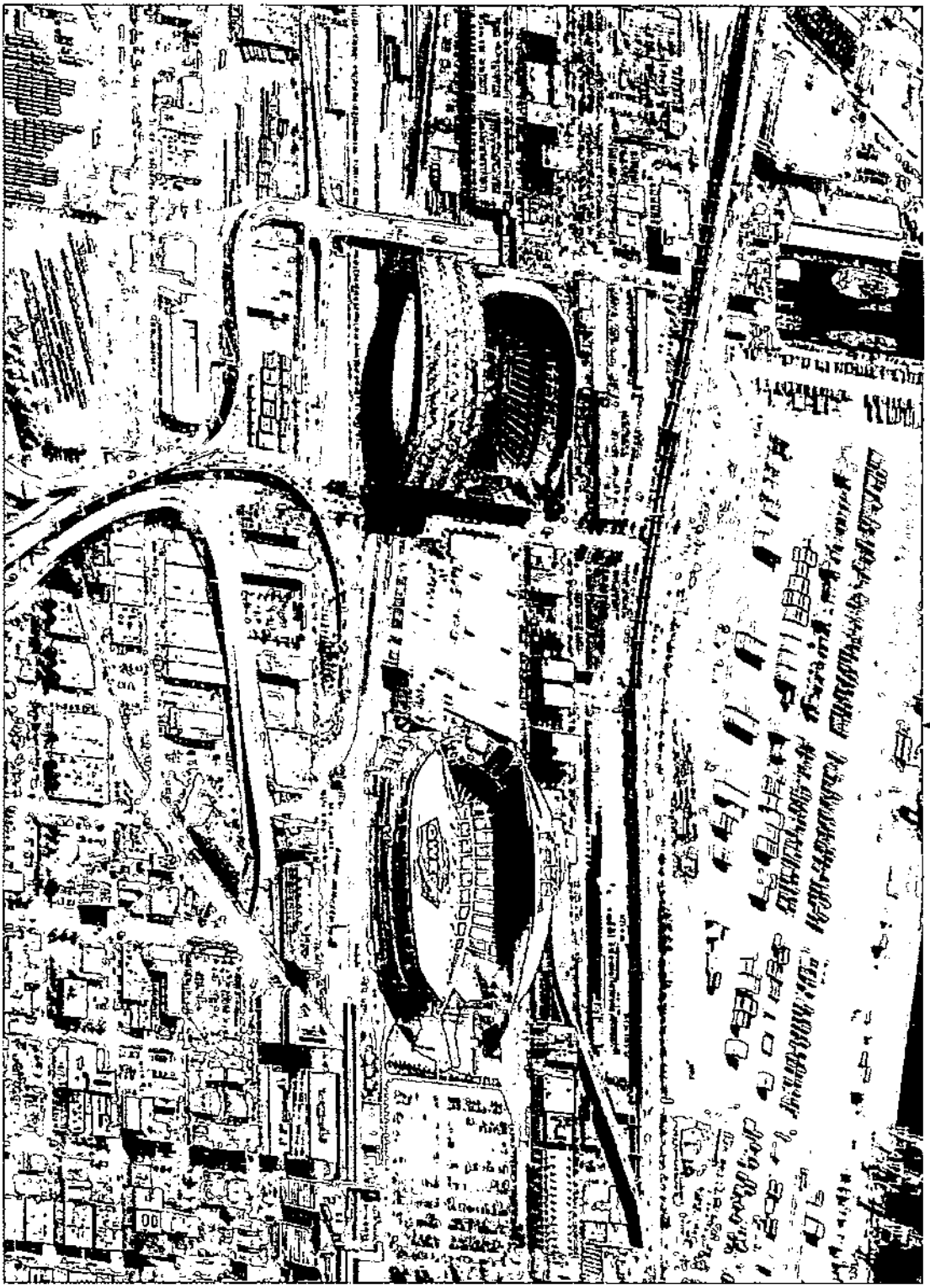


Fig. 4B

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 September 2005 (22.09.2005)

PCT

(10) International Publication Number
WO 2005/088251 A1

(51) International Patent Classification[7]: G01C 11/00, H04N 1/387

(21) International Application Number: PCT/US2005/005689

(22) International Filing Date: 23 February 2005 (23.02.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/548,445 27 February 2004 (27.02.2004) US

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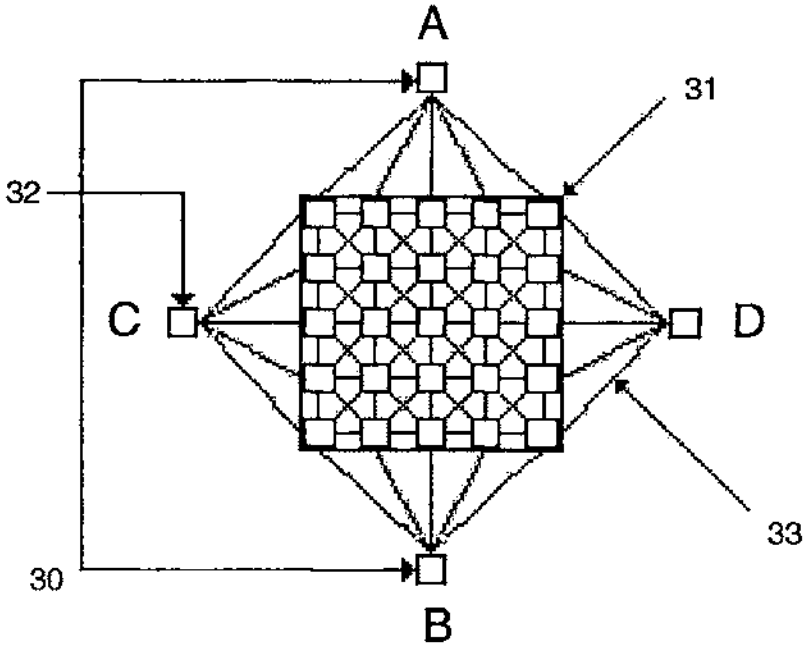
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: FORMING A SINGLE IMAGE FROM OVERLAPPING IMAGES



(57) Abstract: Forming a single image from multiple images is described. A first image and a second image partially overlap to define a common overlap region, and each image has multiple pixels. A boundary between the first image and the second image is automatically calculated based on processed pixel values in the common overlap region. Then the first and second image may be integrated along the boundary to form a single image.

WO 2005/088251 A1

WO 2005/088251 A1



Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Attorney Docket: 2686/112WO

Forming A Single Image From Overlapping Images

Field of the Invention

[0001] The invention generally relates to image processing and, more particularly, the invention relates to forming a single image from multiple images.

Background Art

[0002] Photogrammetry seeks to obtain reliable measurements or information from photographs, images, or other sensing systems. This field is currently being challenged to transition to currently available digital and computer processing technology with fewer file size and memory limitations, faster hardware, and improved software algorithms. Generally, aerial/satellite photographs, survey points of the ground, and other information are first transformed into digital elevation models called "DEMs" (also known as a digital terrain model "DTM"), which are then further processed to produce ortho-rectified photo image files called "orthos".

[0003] Images of large geographical regions commonly are produced from multiple aerially shot pictures integrated into a single picture. For example, many overlapping, individual pictures may be integrated into a single mosaic that forms the final picture of a relevant region. It thus is important to ensure that the boundary between two contiguous pictures in a larger picture is accurately determined to ensure that the two images merge smoothly. When they merge smoothly, the overall image should have the appearance of a single picture.

[0004] Individual images taken of a single region typically have overlapping regions with immediately adjacent images. Accordingly, to determine the boundaries of two adjacent images, for example, the overlapping regions commonly first are roughly aligned. After they are aligned, a seam line is drawn somewhere in the middle of that region (on each of the adjacent pictures) to represent the boundary. This process is prone to error, however, due to its imprecise processes.

[0005] An example of a current commercial photogrammetry product is ImageStation OrthoPro by Z/I Imaging of Intergraph Corporation, which is an ortho production tool that addresses the complete ortho production workflow. Figure 1 shows the Main User Interface for OrthoPro. The "Project Planning" button allows the operator to select the data for a given job, which may include photographs, elevation models, and geo-referenced orthos in various horizontal and vertical datum, projections, and units. This robust functionality avoids the need for the operator to use an external utility to convert the input data to the desired ortho coordinate system. Furthermore, multiple elevation files can be selected, all in different coordinate systems, and prioritized for the automated software to automatically choose which to use during the ortho-rectification process. This avoids the need for the operator to merge DEM files before ortho-rectification. The operator can also select the images of interest, the desired deliverable ortho area(s), and the size of a pixel in ground units. The "Preferences" button allows the operator to turn on or off operator preferences of visual feedback of progress for the job in production. The "Orthorectification", "Dodge", "True Ortho", and "Mosaic" buttons allow for automated processing of orthos, but these buttons are disabled on the user interface until processing of the prior step is complete. If these buttons were enabled, the operator could choose the desired file format and processing options after "Project Planning," but before any processing begins.

[0006] In ortho production programs such as OrthoPro, repetitive human operator intensive processes can create bottlenecks in the production workflow. For example, OrthoPro requires the operator to continuously check the progress of the current step to see if it is complete before the next step can be started. In theory, each step could be automated to start the next step instead of making the operator wait for completion of that step before pushing the button to start the processing of the next step. Then, when processing starts there would be no need to stop until the job is complete. The main issue that prevents the workflow from being automated from beginning images to desired ortho area(s) of interest is the need to acceptably define the seam needed to mosaic the adjacent orthos together. A great deal of operator time can be needed to draw seam lines.

[0007] The need for seam lines arises from limitations associated with file format/size and data collection techniques, which cause images to be separated into partially overlapping

areas. The union of these overlapping areas forms one single large area on the ground referred to as the "project area". The goal is to produce one or more area(s) of interest found within the project area called "product areas". In some cases, the desired product area can be found within a single image, but often the desired product area must be extracted from the union of a combination of more than one of these overlapping areas; i.e. it must be extracted from a mosaic of the originals. A mosaic is the joining images together along seam lines.

[0008] Various algorithms presently exist to determine where to join or fuse the data together to form a seam line. Most algorithms require the operator to do a time-consuming visual quality check to ensure that there are smooth transitions where the data joins along a seam. Ideally, a seam joining the adjacent data should appear undetectable. Realistically, the seam will only be undetectable if the adjacent data has minimal or gradual changes along each side of the seam's edge.

[0009] Many prior automated seam line algorithms are based the Digital Elevation Models (DEMs), but such algorithms cannot predict the radiometric balancing and possible cloud cover in satellite projects without the using the orthos. Furthermore, DEM files must be created and/or maintained to recognize the new buildings or features found along seam lines. Therefore, visual inspection and manual editing is not always avoided using these algorithms.

[0010] OrthoPro provides an automated method to create seam lines, and also provides an option for the operator to edit, save, and import seam lines. But when images overlap more than fifty percent, it becomes confusing where to draw the seam lines. The "Generate Seamlines" button in Fig. 1 avoids such confusion and creates seam lines so that the camera position of the image is more perpendicular to the ground it covers than any other available image camera position. In other words, any point inside the seam lines generated is closer to the position of the camera of that image than any other image; it creates seam lines relative to the most "nadir" camera position. Such a partitioning is generally referred to as Voronoi diagram. This approach helps to increase visibility of the ground and avoids hidden areas due to anything tall obstructing the view of the camera.

[0011] But this automatic method is not perfect. While the algorithm does minimize hidden areas, it does not create substantially undetectable seam lines, and the operator usually will need to adjust the automatically generated seam line. An operator manually adjusting the seam line may find that a lack of survey points near the seam line and less than perfect DEMs will cause two overlapping orthos to have a ground shift relative to each other. In addition, building and tree lean with respect to the camera perspective is also a problem without the time consuming true ortho capabilities. The operator typically must shift back and forth between orthos trying to modify seam lines within the overlap region between the orthos so that there is minimal difference on each side of the seam lines. After the mosaic process is completed, the operator may do a visual quality check of the mosaic to ensure a smooth transition along the seam line. If the seam line was not adequate, the mosaic process must be reperformed. This operator intensive manual seam line editing and the visual quality check of the mosaic is very time consuming.

Summary of the Invention

[0012] A single image is formed from multiple images which partially overlap to define a common overlap region, and each image has multiple pixels. A boundary between the first image and the second image is automatically calculated based on processed pixel values in the common overlap region. Then the first and second image may be integrated along the boundary to form a single image.

[0013] In further embodiments, calculating a boundary includes minimizing a difference between intensity values of pixels adjacent to the boundary. The pixel intensity values may be used as weights which represent short line segments in a shortest path algorithm. Embodiments may further reduce a digital seam associated with the boundary by eliminating redundant segment vertices.

[0014] The boundary calculations may be based on a Voronoi diagram of the first and second images with respect to a camera center point of each image. The first and second images may be ortho-rectified images, aerial images, and/or satellite images of a geographic region.

[0015] Embodiments also include an imaging system adapted to use any of the above methods, and computer software adapted to perform any of the above methods.

Brief Description of the Drawings

[0016] Figure 1 shows the Main User Interface of one commercial ortho production product.

[0017] Figure 2 shows multiple overlapping images which need to be combined into a single image.

[0018] Figure 3 shows a pixel weight grid according to one specific embodiment of the present invention.

[0019] Figure 4 shows potential shortest path grid vectors according to one specific embodiment of the present invention.

[0020] Figure 5 shows reduction of redundant vertex points according to one specific embodiment of the present invention.

Detailed Description of Specific Embodiments

[0021] Various embodiments of the present invention are directed to techniques for automatically processing image pixel data to form a substantially contiguous boundary between a pair of overlapping images. For example, the difference values between corresponding pixel values within overlapping regions of both images may be analyzed to form the boundary. After the boundary is determined, the two images may be integrated together along the boundary to form a substantially unitary single image. Various embodiments of the invention create substantially undetectable seam lines and minimize hidden areas in ortho-image mosaics. This avoids the need for the operator to manually draw, edit, or quality check seam lines since the operator is assured that no better seam line can be created. Details of illustrative embodiments are discussed below. Of course, it should be noted that specific details mentioned below are not necessarily limiting of all embodiments. Many of the discussed embodiments thus are exemplary.

[0022] The seam joining the adjacent orthos should appear undetectable, and this requires that adjacent orthos have minimal or gradual changes along both sides of the seam edge. Various embodiments of the present invention use the difference between the adjacent ortho pixel intensity values as weights digitally representing short line segments in a shortest path algorithm to generate the direction for the least contrast difference between adjacent ortho files.

[0023] The overlap region of the adjacent ortho files is read and the pixels in the overlap region are analyzed to find the differences between the orthos. The algorithm then automatically adjusts where to place the seam lines between the adjacent orthos based upon where the least changes are found. The seam lines are represented digitally as very short fixed magnitude vectors that are created to calculate the refined direction across the overlap region. The digital seam lines can further be reduced by eliminating redundant segment vertices. The approach is somewhat like pouring water down a hill and plotting its course until it reaches the bottom of the hill. Just like the water will find the path of least resistance down the hill, embodiments of the present invention find the best possible seam line to connect adjacent orthos together to form one single large quilt/mosaic of orthos.

[0024] An arbitrarily defined magnitude for the grid size is chosen based upon the size of a pixel relative to the ground coordinate system. Then a grid of points called "grid posts" is calculated in ground coordinates covering the adjacent ortho overlap regions using the grid size to space the grid posts apart. Pixel coordinates are read from the adjacent ortho-rectified files at the ground coordinates of the grid posts. These pixel coordinates are subtracted from their corresponding adjacent ortho pixel coordinates as described in detail below. An adjacency list data structure is used to store the results of the analyzed data thereby minimizing system memory requirements.

[0025] Initial seams are created according to a Voronoi diagram from the ortho-image with the closest camera position. The camera position for each image is used to calculate which image is closer to perpendicular relative to any given ground position within the product area. If the camera position is not readily available, the center of the footprint of each ortho can serve as a good approximation for the camera positions. Given these

ground points, the Voronoi diagram can be calculated which makes an excellent initial and approximate solution to the seam line problem from which the rest of the algorithm refines the seam line. The adjacency list is loaded using the Voronoi diagram to control the order of the loading of the adjacency list. This sets up application of a shortest path calculation which will choose the best path as close to the Voronoi seam lines as possible while creating the path of minimum change across the ortho overlap.

[0026] A weighted graph shortest path algorithm positions the initial seam lines within the overlap regions. The adjacency list holds the pixel weights used as inputs into the shortest path calculation. One purpose of the adjacency list is to track which pixels are adjacent and their weighted connection to each other. The minimum weight path across the adjacent overlap region is then determined.

[0027] Figure 2 shows an example of four separate images, A, B, C, and D, which overlap in the respective shaded regions. For the weight grid calculation for a given overlap region, the ground coordinates within the overlap region are transformed into pixel coordinates, and the pixel intensity values at the calculated (x, y) pixel coordinates are read from the corresponding ortho-image file. The differences between the permutations of these ortho-image pixel intensities for each band are summed and the result is a weight grid for the region.

[0028] Furthermore, all four of the images in Fig. 2 also commonly overlap in the small central square. This region common to all four images will be referred to as the "overlap intersection." The grid posts of the overlap intersection must account for all the adjacent ortho-images in its weighted solution, not just two images. Therefore, the shortest path calculation for the overlap intersection may be processed separately from the other ortho-image overlap regions. The weight grid for this area is computed as:

abs(A-B)+abs(A-C)+abs(A-D)+abs(B-C)+abs(B-D)+abs(C-D)

where abs stands for the absolute value of the difference in the pixel intensity values.

[0029] Figure 3 shows a pixel weighted grid **31** representing the ABCD overlap intersection **30**. An artificial grid post **32** with zero weight is generated to represent each intersecting ortho-image in the overlap intersection **30**. These are shown in Fig. 3 as grid

posts A, B, C, and D representing their respective overlap region border. This artificial grid post **32** is used as a single entry/exit point within the adjacency list to enter/exit the weighted grid **31**. Any grid post along its respective overlap border will be connected to the artificial grid post **32** in the adjacency list and therefore an entry/exit point to the computed solution. The minimum weighted path from A to B is calculated, and then the minimum weighted path from C to D is calculated. After the minimum weight (shortest) path across the grid to connect the artificial pixels has been determined, the artificial pixels will be discarded. The first shortest path pixel connected to each artificial pixel will be the connection point between the overlap region and its corresponding area in the overlap intersection **30**.

[0030] Based on the foregoing description of how to handle overlap intersection areas, handling of the basic two image overlap regions is similar. The weight grid calculation is the same as before, but there are only two ortho-image files to find the weight difference. For example, ortho-images A and B intersect in a common overlap region. The weight grid for the overlap region is computed as abs(A-B). Any known pre-computed grid points from an overlap intersection are utilized and artificial grid posts points are used elsewhere when loading the adjacency list. This algorithm will then determine the minimum weight (shortest) paths across the overlap intersection area. The results will give a seam line across the overlap region to join the overlapping orthos together with minimal contrast difference.

[0031] Using the shortest path algorithm puts the seam lines in digital form. The seam line vertices are created dense in an effort to calculate the correct direction; i.e., the path of least intensity difference. These short vectors will have a possibility of only eight directions and have a constant magnitude equivalent to the size of one grid spacing as shown in Figure 4. The vertex seam line can move one grid post in any direction, but each segment's magnitude is limited by the grid spacing. This connectivity is set up in the adjacency list. The shortest path algorithm will calculate the direction, but not the magnitude of the vectors.

[0032] Once the optimal seam line is determined, redundant vertex points may be removed to reduce processing time. In one specific embodiment, this process may be based on an

algorithm of slope comparison such that points that fall in line without change in grid direction may be removed. For example, the seam line shown in Figure 5A will be reduced to the seam line shown in Figure 5B. By looping through the seam line vertex points looking at the previous and next vertex points to determine if they contain the same direction, the vertex in the center can be quickly removed giving the prior vertex a larger magnitude.

[0033] The final result is an automated process that saves operator time. Embodiments of the present invention make sure that there is no better location to smoothly join the orthos together by analyzing the pixels within the overlap region. Seams are generated that avoid building lean, cloud cover, and areas on the ground that has changed. And operator time is saved since manually drawing mosaic seam lines and/or quality-checking seams no longer needed.

[0034] Embodiments of the invention may be implemented in any conventional computer programming language. For example, preferred embodiments may be implemented in a procedural programming language (*e.g.*, "C") or an object oriented programming language (*e.g.*, "C++"). Alternative embodiments of the invention may be implemented as pre-programmed hardware elements, other related components, or as a combination of hardware and software components.

[0035] Embodiments can be implemented as a computer program product for use with a computer system. Such implementation may include a series of computer instructions fixed either on a tangible medium, such as a computer readable medium (*e.g.*, a diskette, CD-ROM, ROM, or fixed disk) or transmittable to a computer system, via a modem or other interface device, such as a communications adapter connected to a network over a medium. The medium may be either a tangible medium (*e.g.*, optical or analog communications lines) or a medium implemented with wireless techniques (*e.g.*, microwave, infrared or other transmission techniques). The series of computer instructions embodies all or part of the functionality previously described herein with respect to the system. Those skilled in the art should appreciate that such computer instructions can be written in a number of programming languages for use with many computer architectures or operating systems. Furthermore, such instructions may be

stored in any memory device, such as semiconductor, magnetic, optical or other memory devices, and may be transmitted using any communications technology, such as optical, infrared, microwave, or other transmission technologies. It is expected that such a computer program product may be distributed as a removable medium with accompanying printed or electronic documentation (*e.g.*, shrink wrapped software), preloaded with a computer system (*e.g.*, on system ROM or fixed disk), or distributed from a server or electronic bulletin board over the network (*e.g.*, the Internet or World Wide Web). Of course, some embodiments of the invention may be implemented as a combination of both software (*e.g.*, a computer program product) and hardware. Still other embodiments of the invention are implemented as entirely hardware, or entirely software (*e.g.*, a computer program product).

[0036] Although various exemplary embodiments of the invention have been disclosed, it should be apparent to those skilled in the art that various changes and modifications can be made which will achieve some of the advantages of the invention without departing from the true scope of the invention.

What is claimed is:

1. A method of forming a single image from a plurality of images, the method comprising:
for a first image and a second image which partially overlap to define a common overlap region, each image having a plurality of pixels, automatically calculating a boundary between the first image and the second image based on processed pixel values in the common overlap region; and
integrating the first and second image along the boundary to form a single image.

2. A method according to claim 1, wherein calculating a boundary includes minimizing a difference between intensity values of pixels adjacent to the boundary.

3. A method according to claim 2, wherein the pixel intensity values are used as weights which represent short line segments in a shortest path algorithm.

4. A method according to claim 3, further comprising:
reducing a digital seam associated with the boundary by eliminating redundant segment vertices.

5. A method according to claim 1, wherein calculating a boundary is based on a Voronoi diagram of the first and second images with respect to a camera center point of each image.

6. A method according to claim 1, wherein the first and second images are ortho-rectified images.

7. A method according to claim 1, wherein the first and second images are aerial images of a geographic region.

8. A method according to claim 1, wherein the first and second images are satellite images of a geographic region.

9. An imaging system adapted to use the method according to any of claims 1-8.

10. Computer software adapted to perform the method according to any of claims 1-8.

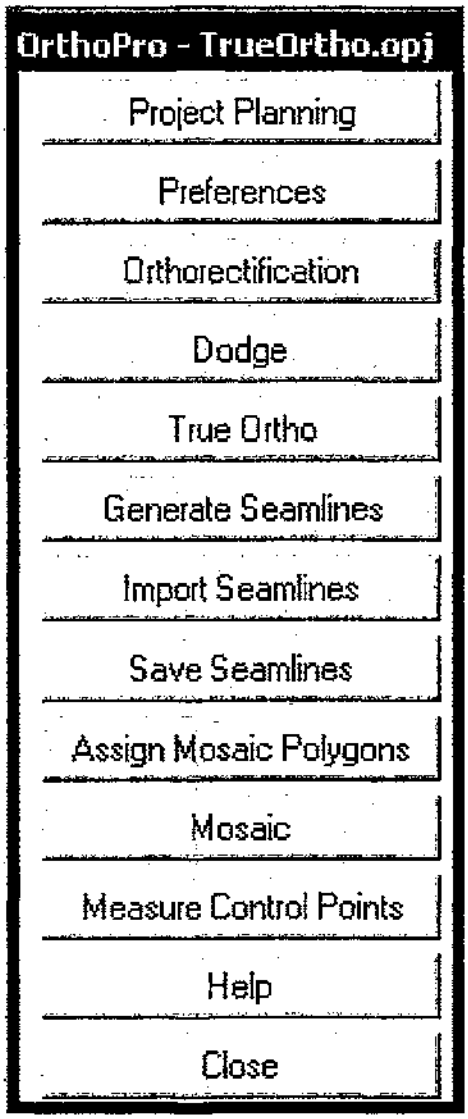

OrthoPro - TrueOrtho.opj
Project Planning
Preferences
Orthorectification
Dodge
True Ortho
Generate Seamlines
Import Seamlines
Save Seamlines
Assign Mosaic Polygons
Mosaic
Measure Control Points
Help
Close

Figure 1

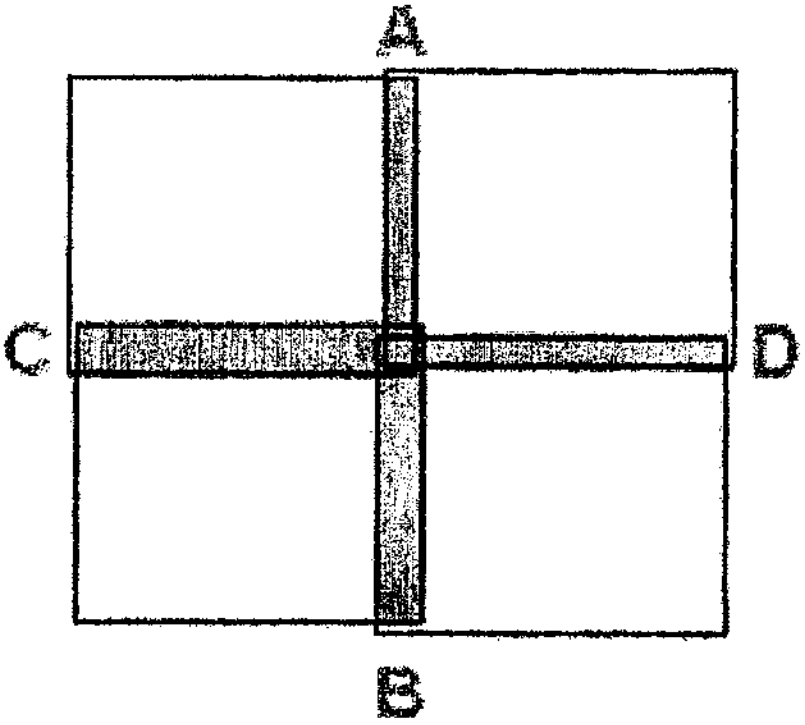


Figure 2

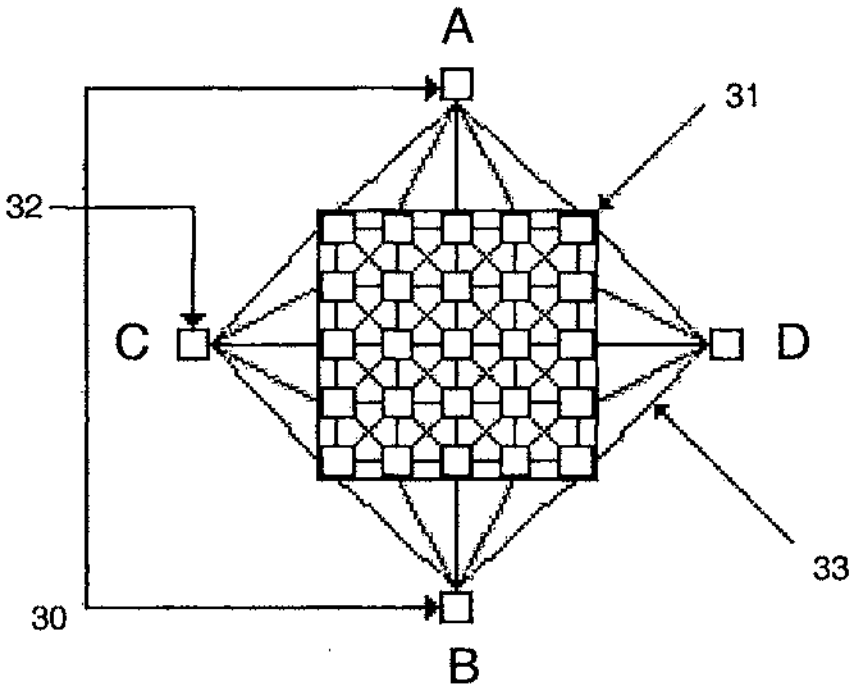


Figure 3

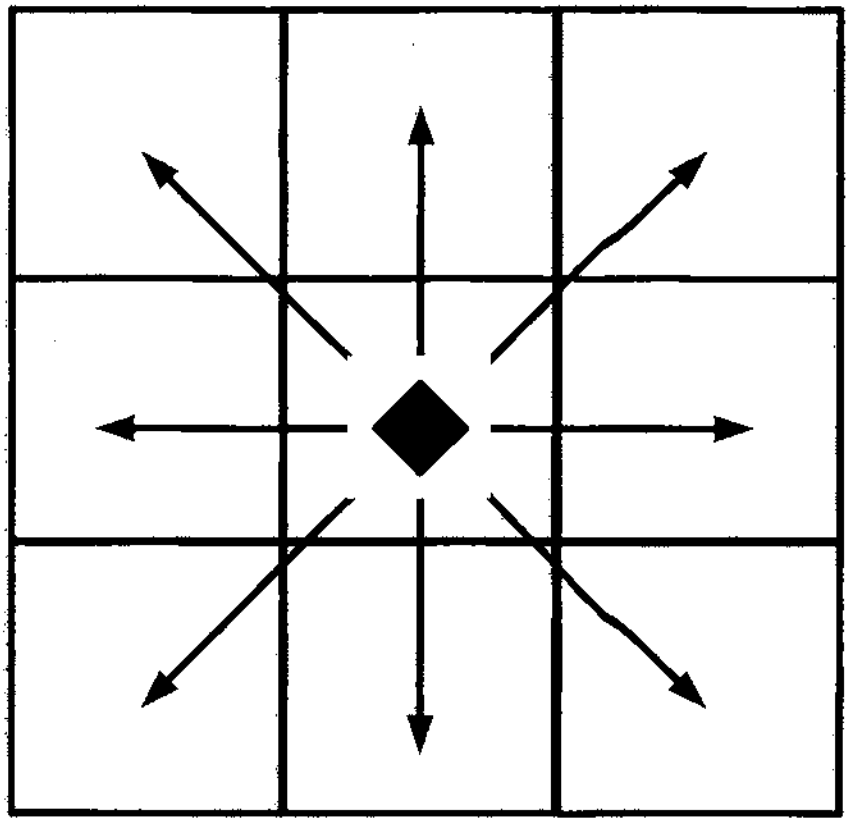
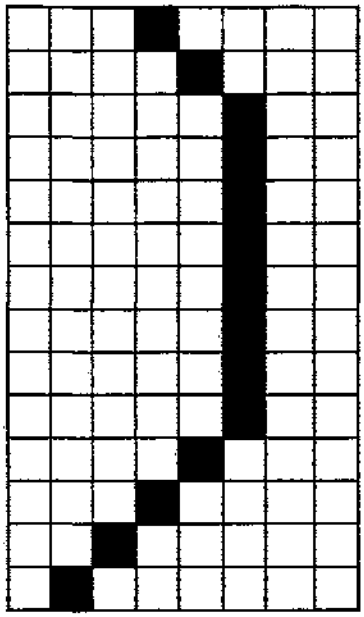
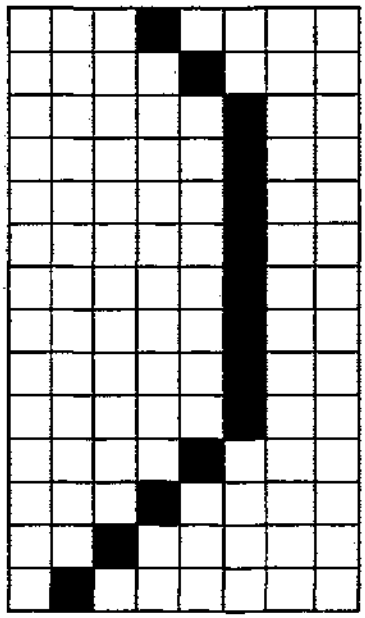


Figure 4



(B)



(A)

Figure 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/005689

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01C11/00 H04N1/387

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01C H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) -& JP 2003 317089 A (DAINIPPON PRINTING CO LTD), 7 November 2003 (2003-11-07)	1-3,9,10
Y	abstract paragraphs '0016! - '0023!	4-8
Y	Orthovista (TM) Software Manual Version 3.3, Release Date 14-01-2002 XP002329753 paragraph '5.2.5!	4-8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 May 2005	10/06/2005

Name and mailing address of the ISA	Authorized officer
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2

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/005689

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2003317089 A	07-11-2003	NONE	

OA80-01 OPTICS - PATENTS 19/04/11 18:32.52
PA PAGE: 1

RENEWAL DETAILS

PUBLICATION NUMBER EP1013966

PROPRIETOR(S)

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DATE FILED 02.12.1999

DATE GRANTED 23.10.2002

DATE NEXT RENEWAL DUE 02.12.2004

DATE NOT IN FORCE 02.12.2004

DATE OF LAST RENEWAL 02.01.2004

YEAR OF LAST RENEWAL 05

STATUS CEASED

**** END OF REPORT ****

REGISTER ENTRY FOR EP1010966

European Application No EP99123877.5 filing date 02.12.1999

Application in German

Priority claimed:
15.12.1998 in Germany - doc: 19857687

Designated States AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

Title METHOD FOR GENERATING A THREE DIMENSIONAL OBJECT DESCRIPTION

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Publication No EP1010966 dated 21.06.2000 and published/granted by EPO
23.10.2002.
Publication in German

Examination requested 07.07.2000

Patent Granted with effect from 23.10.2002 (Section 25(1)) with title METHOD FOR GENERATING A THREE DIMENSIONAL OBJECT DESCRIPTION. Translation filed 16.01.2003

28.01.2003 Notification of change of Address for Service name and address of
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Dated 15.01.2003. Official evidence filed on EP REG MAIN
Entry Type T.1 Staff ID. MMID Auth ID. P51

TIME: 19/04/11 14:33:17

REGISTER ENTRY FOR EP1010966 (Cont.) PAGE: 2

13.02.2003 Patent Granted with effect from 23.10.2002 (Section 25(1)) with title METHOD FOR GENERATING A THREE DIMENSIONAL OBJECT DESCRIPTION. Translation filed 16.01.2003
Entry Type 2.2 Staff ID. MW Auth ID. F54

21.09.2004 Notification of change of Address For Service address of
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[ADP No. 00000059006]
dated 20.09.2004. Written notification filed on GB0393339
Entry Type 7.3 Staff ID. LDAV Auth ID. P30

29.06.2005 Patent ceased on 02.12.2004
Entry Type 12.1 Staff ID. RM86 Auth ID. RM86

**** END OF REGISTER ENTRY ****

DECLARATION

I, Janet Elizabeth Llewellyn, B.A. (Hons.), Diploma in Technical and Specialised Translation, MITI, Technical Translator of D. Young & Co., Briton House, Briton Street, Southampton SO14 3EB, England, do hereby declare that I am conversant with the German and English languages and I certify that the following translation made by me is to the best of my knowledge and belief a true and correct translation of the authentic text for grant of European Patent No. 1010966 prepared in pursuance of The Patents Rules 1995.

Janet Llewellyn

(Janet Llewellyn)

Signed this 7th day of January 2003.

Roofr Exhibit 1002, Page 727

(19) Europäisches Patentamt

European Patent Office

Office européen des brevets

(11) EP 1 010 966 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and publication of Notification of Grant
23.10.2002 Journal 2002/43

(51) Int. Cl.[7]: G01C 11/06

(21) Application No.: 99123877.5

(22) Date of Application: 02.12.1999

(54) Method for generating a three dimensional object description

(84) Designated contracting countries:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 15.12.1998 DE 19857667

(43) Date of publication of application:
21.06.2000 Journal 2000/25

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(56) Documents cited:
DE-A- 4 419 359 DE-A- 19 719 620

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Printed by Jouve, 75001 PARIS (FR)

EP 1010966

The present invention relates to a method of producing a three-dimensional object description of a located spatial object – in particular a building – from stereoscopic pairs of aerial pictures, in which

- from the pairs of aerial pictures two-dimensional image data and stereoscopic parameter data are stored digitised as three-dimensional raw data in a data processing installation,

- two-dimensional orthophoto-data and three-dimensional object data are calculated from the raw data, and

- external object-specific factual data are associated with the three-dimensional object data to form a three-dimensional object description.

The object of this method of measuring is to give a three-dimensional description by way of aerial pictures of spatial objects found on the earth's surface, particularly sites and constructions with spatial boundaries, such as roads, residential housing and industrial buildings, or other buildings. By virtue of the fact that a pair of stereoscopic aerial pictures is recorded for each of the objects, i.e. two aerial pictures in stereoscopic overlap, sets of two-dimensional geometric image data as well as parameter data are obtained which contain highly accurate information about the relative camera angle of the pairs of aerial pictures, absolute shooting co-ordinates and other shooting parameters. This data forms the raw data for calculating oriented representations of the earth's surface which are true to reality. By scanning the individual aerial pictures into an electronic data processing installation digital two-dimensional image data is obtained. In consideration of the stereoscopic parameter data aerial pictures with altitude information are calculated on the basis of them by way of aerotriangulation. In this way, three-dimensional object data is obtained from the original raw data and forms the three-dimensional object description.

The three-dimensional object data has been stored hitherto in data processing installations and has been available for additional evaluation. Topographical maps, traffic route plans, digital models of the ground including three-dimensional accurate point determination are prepared on the basis of the entire store of three-dimensional object data which accrues for getting to know a town or quarter by way of aerial pictures. The accuracy of measurement which can be

achieved makes it quite easy for buildings and parts of buildings to be detected and represented with sufficient accuracy to give angle-related data for constructional and architectural purposes. For example, for the reconstruction of a roof, all relevant information such as roof shape, roof area, roof inclination including any possible peculiarities are detected with sufficient accuracy for that information to be used to prepare an overmeasure.

In the prior art, a method of the kind mentioned in the introduction for detecting and evaluating aerial picture data is described in DE 44 19 359 A1. That method provides that by using the afore-mentioned method steps pairs of aerial pictures are used to prepare three-dimensional models of the earth's surface alongside orthophotographic projections thereof. In that specification, reference is also made to the already known possibility of associating the three-dimensional object data produced from the aerial picture data with external object-specific factual data e.g. land register lines present.

The afore-mentioned prior art does indeed make reference to combining a three-dimensional object data base which is obtained by way of aerial picture assisted measurements with external factual data and making it available to potential users in stored form on data carriers. However, a significant problem with this method which has long since been used in its basic form in photogrammetry for map construction is that extraordinarily extensive object data bases are created which are not without their problems in view of the technical work involved. The work involved in preparing all of the raw data in order to produce a complete three-dimensional object data base is considerable and data processing installations of corresponding efficiency are required. Although the data acquired can basically be stored on high capacity data carriers, e.g. CD-ROMs, transmitting the data using currently available data lines of customary capacity e.g. telephone lines, is extremely tedious and in practice it is virtually unconvertible. Finally, the production of extensive structured data sets is sometimes undesirable in view of data-protection legislation.

DE 197 19 620 A1 relates to a process for the computer-assisted production, processing and use of aerial picture data. The process according to this publication does not, however, essentially transcend that already taught in the afore-mentioned DE 44 19 359 A1. From DE 197 19 620 A1 it can be seen that in the same way analog aerial picture recordings are initially input into a computer system by scanning. Therein, GPS-position data is assigned to the image data which permit the identification of individual objects within the range under

detection. The computer system then uses the scanned aerial pictures to draw up and store three-dimensional model data. The German A-document refers to "object data" since that data, unlike that with the process according to DE 44 19 359 A1, is assigned to individual image objects, such as buildings, villages, open fields etc. By way of this assignment the data for individual three-dimensional object data sets is restricted, thereby making it easier for it to be made available, and also making possible interactive use over the Internet. Over the Internet, the user has access to the aerial picture data ; from the network of data he can download onto his PC the object data of the object of interest to him and evaluate it there in an interactive way.

However, with that previously known process as well, a further problem is that the preparation of the object data is extremely consuming and intensive in terms of memory space. Fast workstations with memory capacities of more than 100 GB are needed. A further problem is that the interactive use of the object data requires special software for the user's PC. That software is proprietary and first of all has to be made available to the potential users, which, in turn, involves a certain expenditure.

The aim of the invention is therefore to avoid the afore-mentioned problems and to reduce the necessary computational expenditure for the production of three-dimensional object descriptions, and to reduce the total amount of data produced therein to such an extent that user-friendly data transmission is possible using relatively low capacity remote data lines. In particular, this involves handling aerial picture data using telephone lines on the World-Wide-Web (Internet). Finally, a general overview of the object descriptions should be possible from the point of view of data-protection legislation.

To solve the problem outlined hereinabove, on the basis of the prior art, the invention proposes a method with the following method steps:

- associating external object-specific factual data with the two-dimensional orthophoto-data for forming object-specific orthophoto-hybrid data sets,

- storing the orthophoto-hybrid sets on a host computer of a networked data processing installation, which host computer is connected to client computers by way of data transmission lines,

- transmitting the orthophoto-hybrid data sets to a client computer by way of the data transmission lines,
- selecting an object-specific orthophoto-hybrid data set at the client computer by inputting the object-specific factual data,
- transmitting the selected object-specific data to the host computer by way of the data transmission lines,
- calculating an object-specific three-dimensional object data set from the three-dimensional raw data which are stored in the host computer and which form the basis for the selected object-specific orthophoto-hybrid data set,
- transmitting the three-dimensional object data set with the object-specific factual data as a three-dimensional object description to the client computer by way of the data transmission lines.

A particular advantage of the method according to the invention results from the fact that rather than a complete three-dimensional object data base being produced, as has been customary hitherto, first of all only a two-dimensional orthophoto-data base is produced, i.e. a two-dimensional projection true to the surface area. The expenditure in terms of data technology in producing, handling and storing this two-dimensional image data is significantly less then if the raw data accruing were to be prepared immediately and completely in three-dimensional manner.

In the next step of the method, the orthophoto-data is structured by adding external factual data. This results in object-specific orthophoto-hybrid data sets. The factual data involved here may be land register-, road- and/or other building data. In this way, a clear association of an address ID with street name and house number is produced for a specific building. The two-dimensional orthophoto-data is stored together with this external factual data in an orthophoto-hybrid data set which is assigned to the specific object.

The afore-mentioned orthophoto-hybrid data sets are stored in the following method step on a host computer i.e. a server. This latter is connected by way of data transmission lines to a data processing installation with a network. This can be both a local network in a business as well as a decentralised extended network, e.g. the Internet of global structure. A number of client-computers are connected to the data transmission lines, and, by way of the data transmission lines, they have access to the data bases of the host computer(s).

In the next step, the orthophoto-hybrid data sets are transmitted by request to any client computer connected to the network. The amount of data which can be overviewed for the two-dimensional image data makes it possible for details from large surface-area aerial pictures to be transmitted even across remote data lines of limited transmission capacity. By way of example, it is possible to envisage the transmission of a picture representation of a village or town sector over the Internet, i.e. via telephone line, by request, to the customer.

The next method step relates to the selection of an object-specific orthophoto-hybrid data set at the client computer. Therein, the user of the client computer, i.e. the customer, can select a specific building e.g. by inputting the address. A particular advantage of the method according to the invention is that now no longer – as hitherto – does a building need to be identified tediously in an aerial picture, but instead for the purposes of selection only the object-specific factual data are input, e.g. the street name and house number. This is quite sufficient for the purpose of selecting an object-specific orthophoto-hybrid data set.

The object-specific factual data selected in the previous method step is now transmitted by data transmission lines from the client computer to the host computer. There, all of the original three-dimensional raw data is available in stored form.

With the aid of the command which has been sent from the client computer by inputting the object-specific factual data, the three-dimensional raw data forming the basis of the object-specific orthophoto-hybrid data set selected on the host computer is then first of all identified in the host computer. This is the aerial picture data and the parameter data, e.g. of a building, or of a house roof. On the basis of the three-dimensional raw data a three-dimensional model computation is then performed in the host computer for the selected object. As a result, a three-dimensional object data set is produced, which, together with the object-specific factual data, forms a complete three-dimensional object description from aerial perspective. In concrete terms, a three-dimensional object description of this kind can contain accurate information about the shape and surface of a house roof, including data about the inclination of the roof, arrangement and size of windows and chimneys, and the like. The clear association with the factual data, such as street and house number, ensures simple and unequivocal access.

Roofr Exhibit 1002, Page 733

Finally, the object data which is prepared in this way, including the associated factual data, is transmitted in the form of a three-dimensional object description to the client by way of data transmission lines. At this point, the three-dimensional data is transmitted across data transmission lines which can in some circumstances have a low transmission capacity. However, the actual amount of data sent is relatively small because the description relates merely to a specific object. Therefore, the technical expenditure here is also substantially less than in the prior art.

Expediently, the external factual data contain the afore-mentioned street- or land register data. However, for a given application, any external data connected in any form to the respective object can in theory be added to the factual data. By way of example, for specific agricultural uses climatic or meteorological data is pertinent, whereas for the development of residential areas or holiday areas local immission data is of importance. The adding of further external factual data can be meaningful depending on the application.

The object description can be represented graphically and/or alphanumerically on the client computer. Expediently, the measurement data which is prepared in the host computer goes so far as to make further processing by the client unnecessary. By way of example, the customer is given extensive measured data relating to a house roof in respect of calculating materials and cost for reconstruction work on a roof by a roofer.

By way of the method according to the invention the possibility is given firstly to a wide circle of users of using aerial picture data for the spatial measurement and description of specific objects. This is done on the principal whereby the raw data which is produced first of all by measurement undergoes two-dimensional preparation. In so doing, following structuring by the integration of external factual data, the restricted amount of data yielded is optimum for processing in a decentralised data processing installation with a network, in particular with transmission lines of small transmission capacity, e.g. the Internet.

A particularly advantageous application of the method according to the invention is in the planning of roof reconstruction work. In this case, the roof of the building forms the object for which a spatial object description is prepared in the way according to the invention. Expediently, the factual data in this case contains street data relating to the building, i.e. street

names, and, additionally, house number. Clearly, land register data or co-ordinates can also be contained as well.

Therein, the roof shape and/or roof surface area is defined in the host computer by partial or fully automated picture analysis methods. Therefore, time-consuming manual processing is abandoned.

Preferably, the orthophoto-data is displayed graphically on the client computer. That display is particularly user-friendly, if, additionally, the factual data of the orthophoto-hybrid data sets is displayed graphically, i.e. mixed in with the orthophoto-data. In the application proposed hereinabove, it is conceivable, for example, for the outline of the roof surface areas which form the objects to be marked graphically, e.g. to be emphasised in colour. This display is particularly user-friendly.

With a preferred further development of the graphic display of the orthophoto-hybrid data sets it is not only the orthophoto-hybrid data and the factual data which are displayed jointly on the client computer, but a graphic user interface is also formed by them, wherein specific orthophoto-hybrid data sets are selectable graphically in an interactive way. This permits user guidance, such as that known within the domain of modern graphic user interfaces. In concrete terms, a marker such as a mouse is moved by way of appropriate input devices across the graphics displayed on the screen, and the desired roof surface area is marked by clicking, for example. In this way, a command is already given to prepare an object description.

Expedient further embodiments of the method according to the invention make provision for data compression before the data is transmitted via the data transmission lines, in order to reduce the amount of data to be transmitted.

Preferably, prior to calculation and transmission of the object-specific three-dimensional object data a security enquiry is installed in order to prevent unauthorised access. Therefore, over and above this, a service for overmeasurement of house roofs can be offered and calculated across the public data network. Therein, sufficient consideration is taken of data protection regulations.

The method according to the invention is described in greater detail hereinafter with the aid of the drawings, wherein:

Figure 1: is a two-dimensional orthophoto display of the roofs of buildings;

Figure 2: is a graphically prepared orthophoto-hybrid data set according to Figure 1;

Figure 3 is a graphic display of a roof evaluation;

Figure 4 is a spatial display of a three-dimensional object description of the building according to Figure 3.

Figure 1 shows the orthophotographic display, produced from a corresponding pair of aerial pictures, of a number of house roofs. According to the method of the invention, this picture is stored in the form of two-dimensional orthophoto-data in a host computer which may be connected to the Internet, for example.

The part of the picture shown is merely selected for the sake of clarity. The display of individual buildings, a street, or an entire town sector can be called up on the client computer which is connected by data lines to the afore-mentioned host computer.

The orthophoto-data is structured in accordance with extreme factual data, e.g. street details, and, in addition, house numbers. In Figure 2, the orthophoto-data set shown graphically in Figure 1 is prepared into an ortho-photo-hybrid data set by the addition of external factual data. For example, a street is emphasised graphically by the light line. Additionally, one individual building is marked graphically by a circle. With a user interface of this kind, the customer, i.e. the end user on the client computer is able, by interactive graphic data input, to select the building marked with the circle, for example.

After selecting the building, a command is sent to the host computer via the data lines. On the basis of the three-dimensional raw data present there a stereoscopic model description of the roof is formulated. Using image analysis processes, it is therein possible to detect the information relating to the roof description which is necessary for the reconstruction work –

roof surface area, roof shape, ridge lines, eave lines, chimneys, windows, roof tops, with sufficient accuracy.

The orthophoto-hybrid data set can be further processed to form technical graphics giving dimensions, as shown in Figure 3.

The three-dimensional object description worked out on the basis of this is, alternatively, emitted in a planar, two-dimensional graphic display, as in Figure 3, and/or in a perspective, spatial display, as in Figure 4, and transmitted to the client computer. At the same time, the factual data is prepared and added alphanumerically to the image data transmitted. Thus, for example, the roof surface area is given in m^2 in order to give a first impression of the extent of the roof reconstruction work needed.

The data for transmission may possibly be compressed in order to limit expenditure. Expediently, security enquiries are executed for the purpose of preventing unauthorised use and for the purpose of making payments for services rendered.

CLAIMS

1. A method of producing a three-dimensional object description of a located spatial object - in particular a building - from stereoscopic pairs of aerial pictures, in which

- from the pairs of aerial pictures two-dimensional image data and stereoscopic parameter data are stored digitised as three-dimensional raw data in a data processing installation,

- two-dimensional orthophoto-data and three-dimensional object data are calculated from the raw data, and

- external object-specific factual data are associated with the three-dimensional object data to form a three-dimensional object description,

characterised by the method steps:

- associating external object-specific factual data with the two-dimensional orthophoto-data for forming object-specific orthophoto-hybrid data sets,

- storing the orthophoto-hybrid data sets on a host computer of a networked data processing installation, which host computer is connected to client computers by way of data transmission lines,

- transmitting the orthophoto-hybrid data sets to a client computer by way of the data transmission lines,

- selecting an object-specific orthophoto-hybrid data set at the client computer by inputting the object-specific factual data,

- transmitting the selected object-specific factual data to the host computer by way of the data transmission lines,

- calculating an object-specific three-dimensional object data set from the three-dimensional raw data which are stored in the host computer and which form the basis for the selected object-specific orthophoto-hybrid data set, and

- transmitting the three-dimensional object data set with the object-specific factual data as a three-dimensional object description to the client computer by way of the data transmission lines.

2. A method according to claim 1 characterised in that the object is the roof of a building.

3. A method according to claim 2 characterised in that the factual data include street data of the building.

4. A method according to claim 1 characterised in that the factual data include land register data.

5. A method according to claim 1 characterised in that the orthophoto-data are graphically represented at least on a client computer.

6. A method according to claim 1 characterised in that the factual data of the orthophoto-hybrid data sets are graphically represented.

7. A method according to claim 1 characterised in that the orthophoto-hybrid data and the factual data are graphically represented on a client computer jointly in the form of a graphical user interface, wherein a specific orthophoto-hybrid data set can be interactively graphically selected.

8. A method according to claim 1 characterised in that the host computer is an Internet server.

9. A method according to claim 1 characterised in that the data network is the World Wide Web.

10. A method according to claim 2 characterised in that determination of the roof shape and/or the roof area is effected in the host computer by at least partially automated image analysis processes.

11. A method according to claim 1 characterised in that data compression is effected in each case prior to a transmission of data by way of data transmission lines.

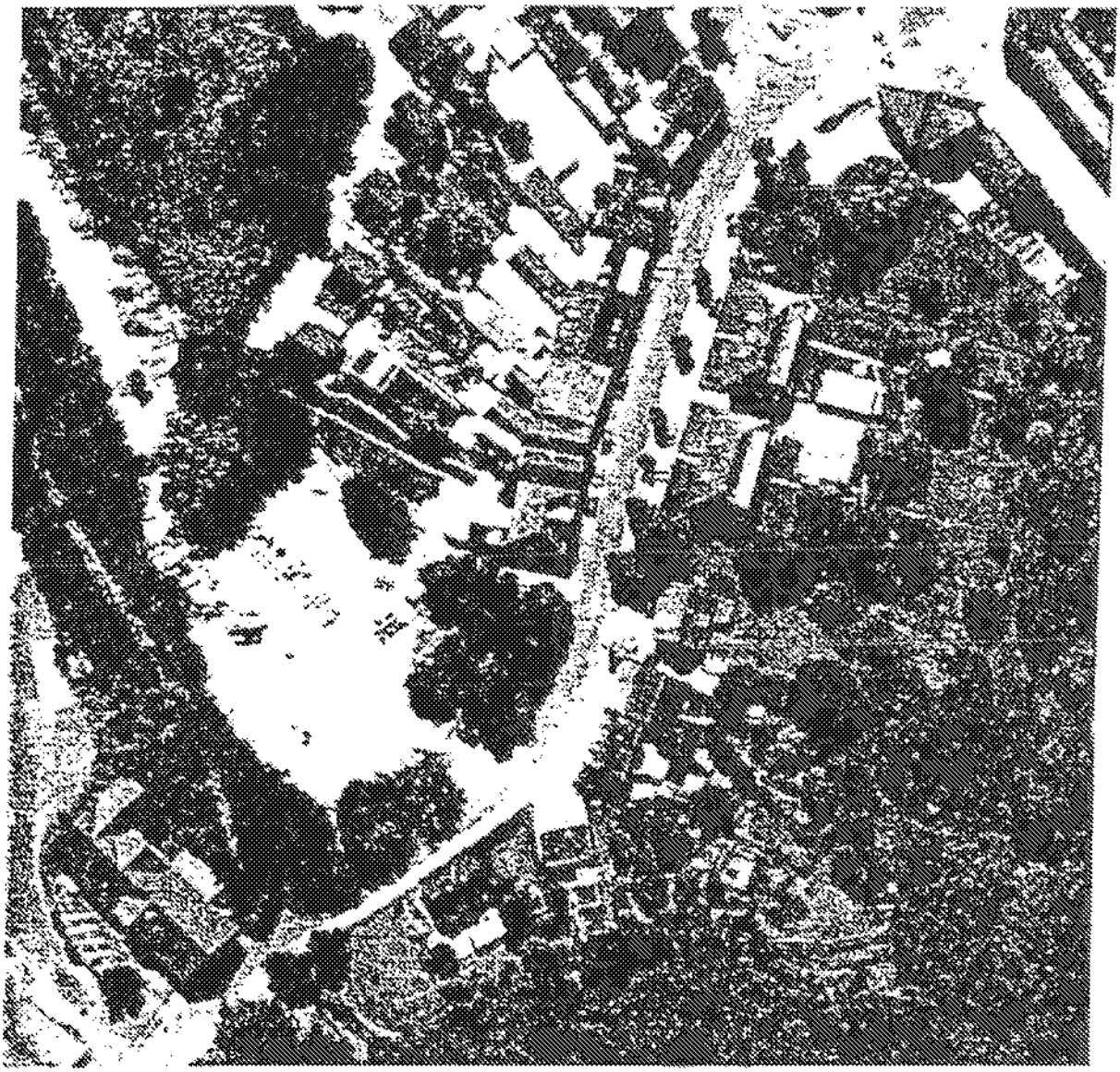
12. A method according to claim 1 characterised in that a security enquiry is executed prior to calculation of the object-specific three-dimensional object data set.

13. A method according to claim 1 characterised in that further external factual data are added to the object-specific three-dimensional object data set.

02. 1999 99123877.6 DRAW

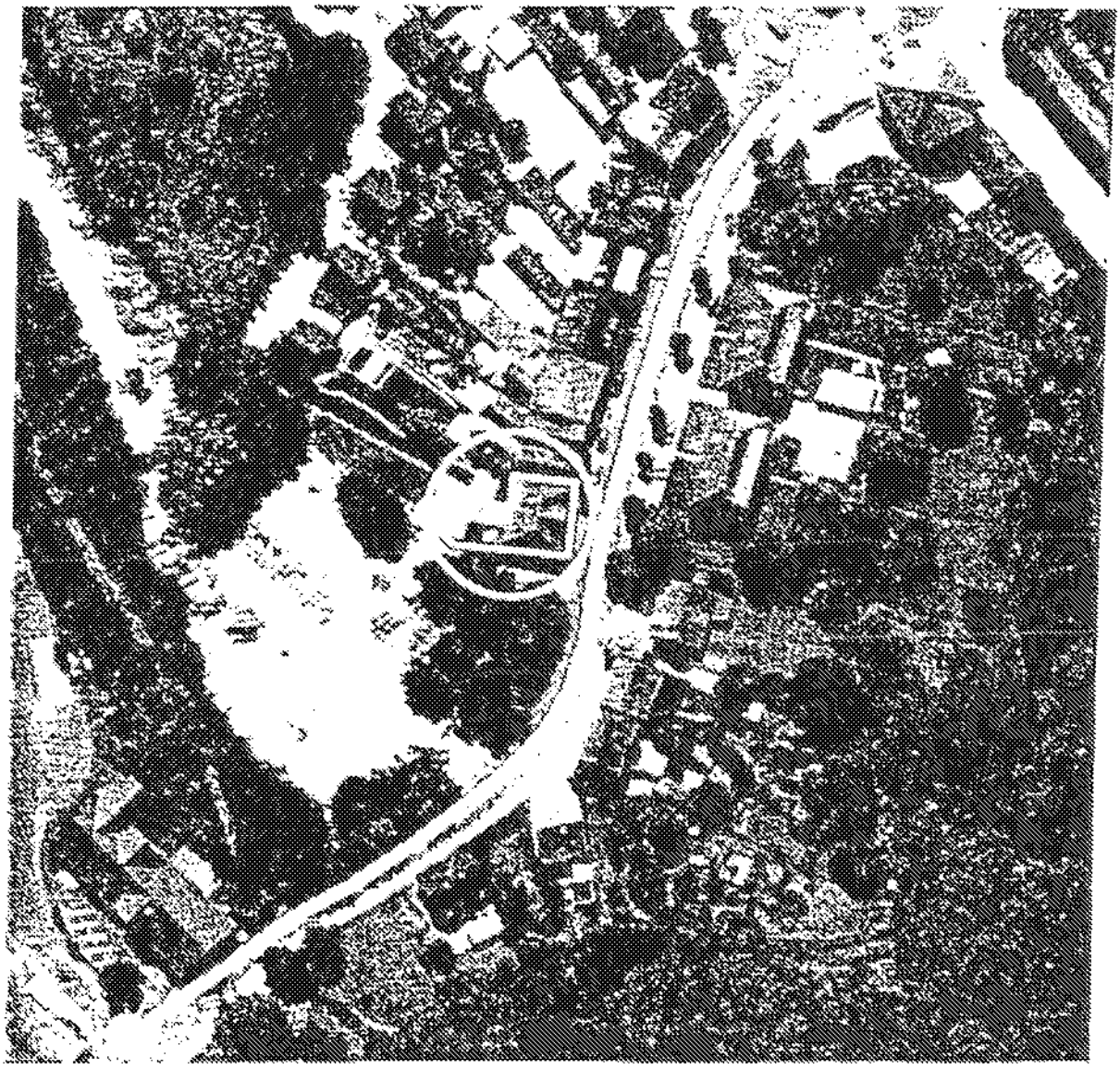
EPO-Munich
59
02. Dez. 1999

Fig.1



02 1999 99123877.5 DRAW

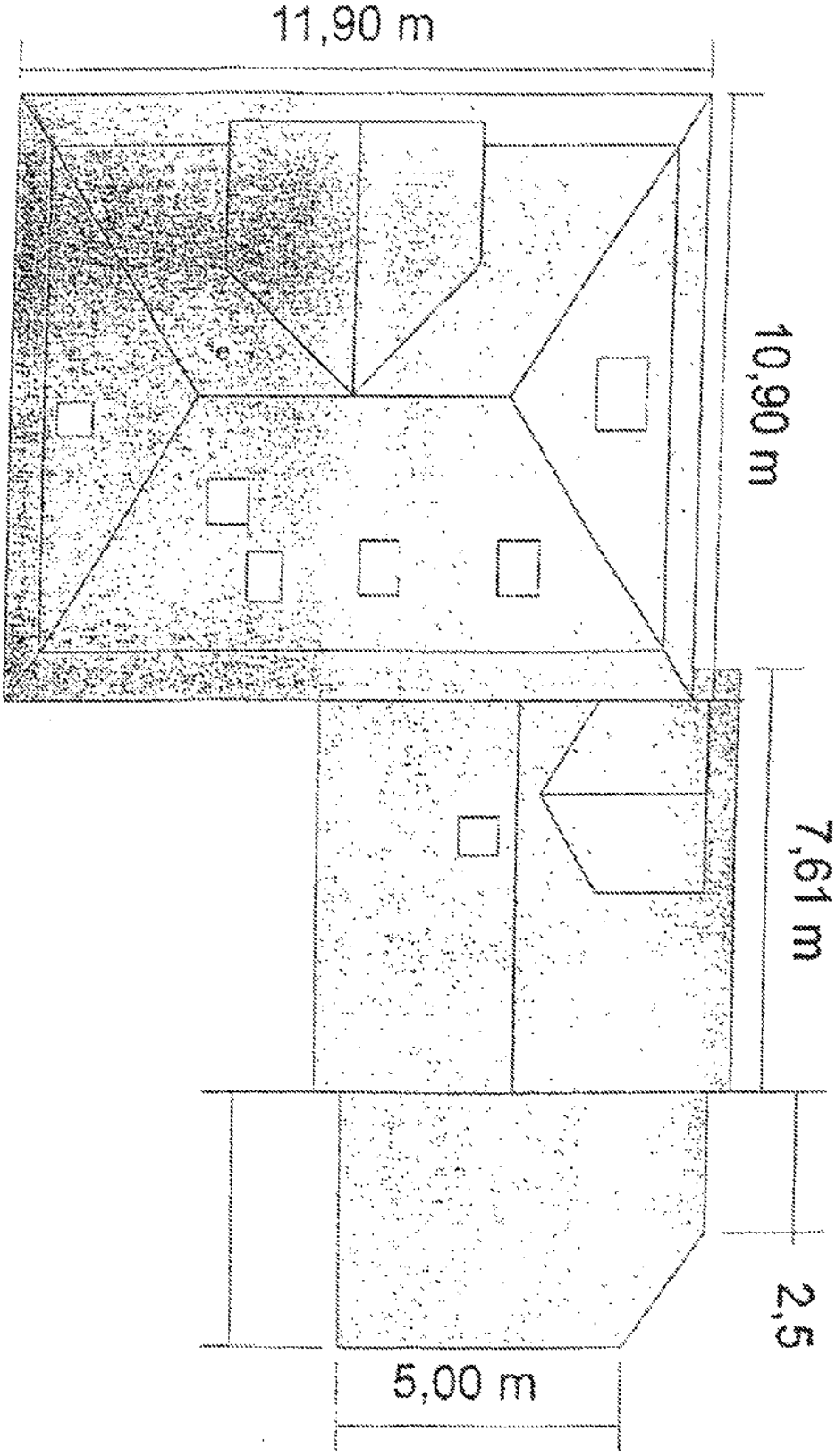
Fig.2



noted:25-08-2000

02-12-1999 9912387.5 DRAW

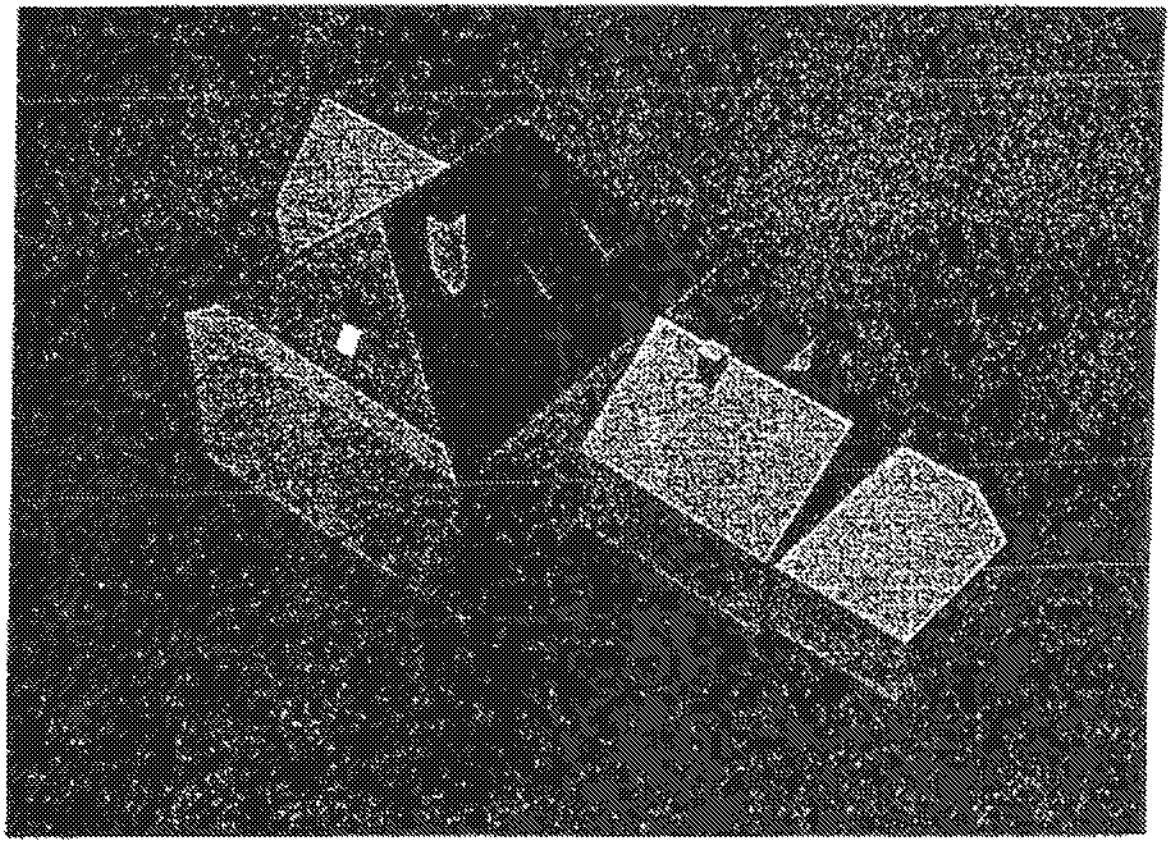
Fig.3



60:25-09-2000

08 -1999 99123077.6 DRAW

Fig.4



Int.Cl.[1.25-08-2000]

PCT/US2013/032760

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
BROCKHAUS MARC A.

DUNLAP CODDING, P.C. P.O. BOX 16370 OKLAHOMA CITY OK 73113 USA

DOCKETED

wdp

Notify Client/VA: WC 07/31/2013
check Family for PA 08/10/2013
Voluntary Amendment 09/10/2013
Resp to Written Opin 10/10/2013

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference ~~5139.854WO~~ 6358.215WC	Date of mailing *(day/month/year)* 10 July 2013 (10.07.2013)
International application No. **PCT/US2013/032760**	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
Applicant **PICTOMETRY INTERNATIONAL CORP. et al**	International filing date *(day/month/year)* **18 March 2013 (18.03.2013)**

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 . 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.
In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	Authorized officer COMMISSIONER
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-8755

Form PCT/ISA/220 (July 2010)

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for three months from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT Services => PCT Services

ID : PCT international application number
PW : **5985BG48**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com

Email: ipkc@ipkcenter.com

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 5129.854WO	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. **PCT/US2013/032760**	International filing date *(day/month/year)* **18 March 2013 (18.03.2013)**	(Earliest) Priority Date *(day/month/year)* 19 March 2012 (19.03.2012)

Applicant

PICTOMETRY INTERNATIONAL CORP. et al

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of :
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____ , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38 2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/032760

A. CLASSIFICATION OF SUBJECT MATTER

G06Q 50/10(2012.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06Q 50/10; G06F 3/048; G06F 17/60; G06Q 30/00; G06Q 50/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:location, roof, property, report, image

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-123589 A (DAINIPPON PRINTING CO., LTD.) 26 April 2002 See paragraphs [0006]-[0009], [0018]-[0026], [0031]-[0032], [0047]-[0053], [0067]-[0072], claims 1-2, 8-9 and figures 4-10.	1-13
Y	US 2006-0036513 A1 (JERRY WHATLEY et al.) 16 February 2006 See abstract, paragraphs [0024], [0032]-[0035], claims 1-2, 8 and figures 2-4b.	1-13
A	JP 2001-306667 A (OSHIMA KENJI) 02 November 2001 See paragraphs [0014]-[0017], [0029]-[0030], claims 1-3 and figures 7-14, 20.	1-13
A	US 2009-0259568 A1 (LEE CHUN KYOUNG) 15 October 2009 See abstract, claims 1-4 and figures 1-4, 7-9.	1-13
A	JP 2006-031087 A (NEC CORP.) 02 February 2006 See abstract, claims 1-3, 7-8 and figures 3-4.	1-13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 July 2013 (09.07.2013)	**10 July 2013 (10.07.2013)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	OH Eung Gie Telephone No. +82-42-481-8744

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/032760

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2002-123589 A	26/04/2002	None	
US 2006-0036513 A1	16/02/2006	US 2002-0052755 A1	02/05/2002
JP 2001-306667 A	02/11/2001	None	
US 2009-0259568 A1	15/10/2009	EP 2033155 A1	11/03/2009
		EP 2033155 A4	20/07/2011
		JP 2009-540427 A	19/11/2009
		JP 4933613 B2	16/05/2012
		KR 10-1084374 B1	16/11/2011
		KR 10-2009-0015120 A	11/02/2009
		US 2008-154740 A1	26/06/2008
		WO 2007-142494 A1	13/12/2007
JP 2006-031087 A	02/02/2006	None	

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
BROCKHAUS MARC A.

DUNLAP CODDING, P.C. P.O. BOX 16370 OKLAHOMA CITY OK 73113 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	10 July 2013 (10.07.2013)
Applicant's or agent's file reference	FOR FURTHER ACTION
5129.854WO	See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2013/032760	**18 March 2013 (18.03.2013)**	19 March 2012 (19.03.2012)

International Patent Classification (IPC) or both national classification and IPC

G06Q 50/10(2012.01)i

Applicant

PICTOMETRY INTERNATIONAL CORP. et al

1. This opinion contains indications relating to the following items:

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	09 July 2013 (09.07.2013)	OH Eung Gie Telephone No. +82-42-481-8744

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2013/032760

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

   a. a sequence listing filed or furnished
      ☐ on paper
      ☐ in electronic form

   b. time of filing or furnishing
      ☐ contained in the international application as filed.
      ☐ filed together with the international application in electronic form.
      ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additioanl copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2013/032760

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-13	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-13	NO
Industrial applicability (IA)	Claims	1-13	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: JP 2002-123589 A (DAINIPPON PRINTING CO., LTD.) 26 April 2002
D2: US 2006-0036513 A1 (JERRY WHATLEY et al.) 16 February 2006

1. Novelty and Inventive Step

1.1 Claims 1-12

1.1.1 Independent claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a method comprising the steps of: searching map information of selected real estate information; determining real estate information which suits an input search conditions including position information; displaying map information which has a searched area where a property object contained in real estate information consisting of the searched conditions; and determining a real estate contractor and selecting the real information based on the search conditions including an area-along-the-railroad-line, area, room arrangement and house rent (See paragraphs [0019]-[0025], [0031]-[0032], [0050]-[0053], claim 1, 8-9 in D1). Claim 1 differs from D1 in determining a footprint of the roof and determining predominant pitch of the roof. However, D2 discloses a method comprising the steps of: displaying pictures of the property; and providing a summary of details such as contact information, the address of the property, the type of property including a property outline like a size (See paragraphs [0032]-[0034] in D2). Claim 1 would have been obvious over D1 and D2. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

1.1.2 Dependent claims 2-12

The additional feature of claim 2 is identical to the feature of D1 in providing detailed information on a specific property object, wherein the property object includes house rent, room arrangement, conditions and map displaying interest of the geographic location of the real estate (See paragraphs [0026], [0067]-[0072], claims 1, 8-9 in D1). Claim 2 would have been obvious over D1 and D2. Therefore, claim 2 lacks an inventive step under PCT article 33(3).

Continued on Supplemental Box

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2013/032760

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of: Box No. V

The additional feature of claim 3 is identical to the feature of D2 in that the details include a summary of details such as contact information (See paragraph [0032], figure 2 in D2). Claim 3 would have been obvious over D1 and D2. Therefore, claim 3 lacks an inventive step under PCT article 33(3).

The additional feature of claim 4 discloses the set of instructions comprising a first computer readable medium of a first host system and a second computer readable medium of a second host system, but this feature of claim 4 is considered to be a minor difference, over the disclosure of D1 and D2, which falls under the general knowledge of a person skilled in the art. Therefore, claim 4 lacks an inventive step under PCT article 33(3).

The additional feature of claim 5 is identical to the feature of D1 in identifying the location of real estate for displaying property information (See paragraphs [0006]-[0009] in D1). Claim 5 would have been obvious over D1 and D2. Therefore, claim 5 lacks an inventive step under PCT article 33(3).

The additional feature of claim 6 is identical to the feature of D1 in receiving inputted search conditions including location information (See claims 1-2 in D1). Claim 6 would have been obvious over D1 and D2. Therefore, claim 6 lacks an inventive step under PCT article 33(3).

The additional feature of claim 7 is virtually suggested by the feature of D1 in that the geographic location is selected by inputting a location (See paragraph [0067] in D1). Claim 7 would have been obvious over D1 and D2. Therefore, claim 7 lacks an inventive step under PCT article 33(3).

The additional feature of claim 8 is virtually suggested by the feature of D2 in showing a category of graphic objects and selecting object's dimensions (See paragraph [0035] in D2). Claim 8 would have been obvious over D1 and D2. Therefore, claim 8 lacks an inventive step under PCT article 33(3).

The additional feature of claim 9 is identical to the feature of D1 in displaying a two-dimensional image and three-dimensional image of the position of the property object (See paragraphs [0018], [0023], [0047]-[0049] in D1). Claim 9 would have been obvious over D1 and D2. Therefore, claim 9 lacks an inventive step under PCT article 33(3).

Claims 10-11 further comprise determining the predominant pitch which includes determining a plurality of pitch values, the predominant pitch being based on the pitch values. However, the additional features of claims 10-11 are merely matters of design option when the general knowledge in relevant field of the art is used. Claims 10-11 would have been obvious over D1 and D2. Therefore, claims 10-11 lack an inventive step under PCT Article 33(3).

The additional feature of claim 12 is identical to the feature of D1 in providing the property object which includes a map displaying interest of the geographic location of the real estate (See paragraphs [0067]-[0072], claims 1, 8-9 in D1). Claim 12 would have been obvious over D1 and D2. Therefore, claim 12 lacks an inventive step under PCT article 33(3).

Continued on The Next Page

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2013/032760

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of: Previous Page

1.2 Claim 13

Claim 13 relates to a system comprising two or more host systems, but it shares the same technical features of a set of instructions with a claim 1. Accordingly, the same reasoning as in claim 1 applies to claim 13. Therefore, claim 13 lacks an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-13 are industrially applicable under PCT Article 33(4).

Electronic Patent Application Fee Transmittal

Application Number:	13424054
Filing Date:	19-Mar-2012
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Marc Alan Brockhaus/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	2806	1	90	90
			Total in USD ($)	**90**

Electronic Acknowledgement Receipt

EFS ID:	20457942
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Marc Alan Brockhaus/Lori Radford
Filer Authorized By:	Marc Alan Brockhaus
Attorney Docket Number:	6338.157
Receipt Date:	20-OCT-2014
Filing Date:	19-MAR-2012
Time Stamp:	12:34:01
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$90
RAM confirmation Number	9721
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	6338157_Transmittal10202014.pdf	66383	no	1
Warnings:					
Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	6338157_IDS.pdf	617813	no	10
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Foreign Reference	F1_F10.pdf	10948354	no	260
Warnings:					
Information:					
4	Foreign Reference	F11_F20.pdf	16625133	no	357
Warnings:					
Information:					
5	Non Patent Literature	NPL1_NPL13.pdf	22843030	no	130
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6	Non Patent Literature	NPL14a.pdf	24981132	no	199
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7	Non Patent Literature	NPL14b.pdf	25540082	no	200
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8	Non Patent Literature	NPL15_NPL32.pdf	22453488	no	138
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9	Non Patent Literature	NPL33a.pdf	20109431	no	83

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10	Non Patent Literature	NPL33b.pdf	18688215 f05e884d338e3278deee1beccb2169fbe844...2d0b	no	83
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11	Non Patent Literature	NPL34_NPL66.pdf	25496597 58d4b4bbe5e96a490d99a4401ebb4f0d...c696	no	265
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12	Non Patent Literature	NPL67_NPL74.pdf	23029642 0ae47bb757e4a2c96e8410c30ae6c1d38...f44af	no	231
Warnings:					
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13	Non Patent Literature	NPL75_NPL84.pdf	7271147 707e4d3bfb56708ecc9e27e6e1da8cb8765...bf54e	no	41
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14	Non Patent Literature	NPL85_NPL90.pdf	9196207 76fb7041e9b771740b7a9869d0bb3fe935a84811d4497	no	105
Warnings:					
Information:					
15	Non Patent Literature	NPL91_NPL95.pdf	18280857 a91bd887ba5dbc8833eb7e7947a79d1388899e9...1e8aa	no	194
Warnings:					
Information:					
16	Non Patent Literature	NPL96.pdf	1235765 6d0b7e80ecabd2beeeb0a80d9d1eeb0a8868e70...0f06b	no	12
Warnings:					
Information:					
17	Non Patent Literature	NPL97.pdf	442381 b8e8307116a92ce97ab4e1e17408e8576da8f...4a6e	no	10
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18	Fee Worksheet (SB06)	fee-info.pdf	30294 /9041f5a22e9fa6cf1b6981bb2a4120 4bf7/	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	247855951

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Doc Code: TRAN.LET

Document Description: Transmittal Letter

PTO/SB/21 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew E. Zimmerman
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
- ☐ Fee Attached
- ☐ Amendment/Reply
- ☐ After Final
- ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☑ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
- ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
- ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please identify below):

See Remarks

Remarks

ELECTRONICALLY TRANSMITTED:
1. SB21 Transmittal Form (1 pg);
2. Information Disclosure Statement (10 pgs); and
3 Referenced Foreign and Non-patent literature documents

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	DUNLAP CODDING, P.C.		
Signature	Ann M. Robl		
Printed name	Ann M. Robl		
Date	10/20/2014	Reg. No.	71,541

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Ann M. Robl		
Typed or printed name	Ann M. Robl	Date	10/20/2014

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

30589 7590 11/28/2014

DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

EXAMINER	
ZIMMERMAN, MATTHEW E	

ART UNIT	PAPER NUMBER
3684	

NOTIFICATION DATE	DELIVERY MODE
11/28/2014	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

dsorocco@dunlapcodding.com

Office Action Summary	Application No. 13/424,054	Applicant(s) THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *10/20/2014*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-18* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-18* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.

4) ☐ Other: _____.

1. The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Status of Claims

2. Claim(s) 1-18 have been examined.

Drawings

Information Disclosure Statement

3. The information disclosure statement filed 10/20/2014 fails to comply with 37 CFR 1.98(a)(3) because it does not include a concise explanation of the relevance, as it is presently understood by the individual designated in 37 CFR 1.56(c) most knowledgeable about the content of the information, of each patent listed that is not in the English language. It has been placed in the application file, but the information referred to therein has not been considered.

Claim Rejections - 35 USC § 101

4. 35 U.S.C. 101 reads as follows:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

5. Claims 1-18 are rejected under 35 U.S.C. 101. The claimed invention is directed to non-statutory subject matter because the claim(s) as a whole, considering all claim

elements both individually and in combination, do not amount to significantly more than an abstract idea. The claim(s) is/are directed to the abstract idea of estimating area. The additional element(s) or combination of elements in the claim(s) other than the abstract idea per se amount(s) to no more than: (i) mere instructions to implement the idea on a computer, and/or (ii) recitation of generic computer structure that serves to perform generic computer functions that are well-understood, routine, and conventional activities previously known to the pertinent industry. Viewed as a whole, these additional claim element(s) do not provide meaningful limitation(s) to transform the abstract idea into a patent eligible application of the abstract idea such that the claim(s) amounts to significantly more than the abstract idea itself. Therefore, the claim(s) are rejected under 35 U.S.C. 101 as being directed to non-statutory subject matter.

Claim Rejections - 35 USC § 102

6. The following is a quotation of the appropriate paragraphs of pre-AIA 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

7. Claims 14-18 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Thornberry (US 2010/0296693).

Referring to claims 14-18, Thornberry teaches:

- receiving [data] (*see Thornberry Fig. 4A-B*);

- providing [data] (*see Thornberry Fig. 4A-B*);

The Examiner notes that the data provided and data received is non-functional descriptive material because it does functionally affect the way in which the receiving and providing are performed.

Remarks

8. In regards to the rejections under 35 U.S.C. 101, the present amendments have overcome the prior rejections under this section. However, the amendments have necessitated a new rejection under 35 U.S.C. 101. Accordingly, claims 1-13 are not in condition for allowance because they are rejected under 35 U.S.C. 101.

9. In regards to the response by the applicant to the prior prior art rejections, the Examiner notes that the applicant's remarks were persuasive and the rejections have been withdrawn. The Examiner agrees that the prior art of record fails to teach "predominant pitch" as explained in paragraphs [0076] to [0078] and Fig. 7 of the applicant's specification. Predominant pitch as explained by the remarks and specification is completely different than a pitch and involves a weighted average of individual pitch factors for two or more portions of a roof according to the formulas and description in the abovementioned paragraphs.

Conclusion

10. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP

§ 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW ZIMMERMAN whose telephone number is (571)270-5278. The examiner can normally be reached on Mon-Fri 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jason B. Dunham can be reached on (571) 272-8109. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW ZIMMERMAN/
Primary Examiner, Art Unit 3684

Notice of References Cited	Application/Control No. 13/424,054	Applicant(s)/Patent Under Reexamination THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2010/0296693	11-2010	Thornberry et al.	382/100
*	B	US-8,078,436	12-2011	Pershing et al.	703/2
*	C	US-2010/0114537	05-2010	Pershing, Chris	703/1
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	http://www.eagleview.com/Portals/0/PortalContent/EagleView-iPhone-Application-Guide.pdf, 2011
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

ELECTRONICALLY FILED ON: October 20, 2014

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

Substitute for form PTO/SB/08a

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	ZIMMERMAN, MATTHEW E.
Attorney Docket Number	6338.157

U. S. PATENT DOCUMENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	P1	2,273,876		02/24/1942	Lutz et al.	
	P2	3,153,784		10/20/1964	Petrides et al.	
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Use the following tools to estimate the area and the materials needed for the roof. The "House Base Area" is the area of the land the house covers. When measuring, be sure to include the eaves covered areas. Our area calculator can be used to estimate the area coverage of the house. If the house is irregular in shape, you can divide the house covered area into a few simple shapes and add their area together. The roof pitch defines the steepness of the roof. It can be measured or can be estimated via by comparing your roof with our images.

Roofing Area Calculator

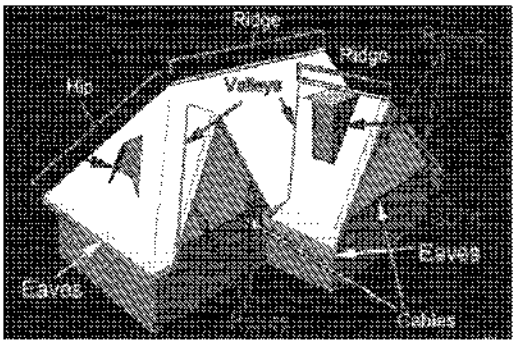
House Base Area [ ] square foot
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Calculate

Roofing Material Calculator

Roof Area [ ] square foot
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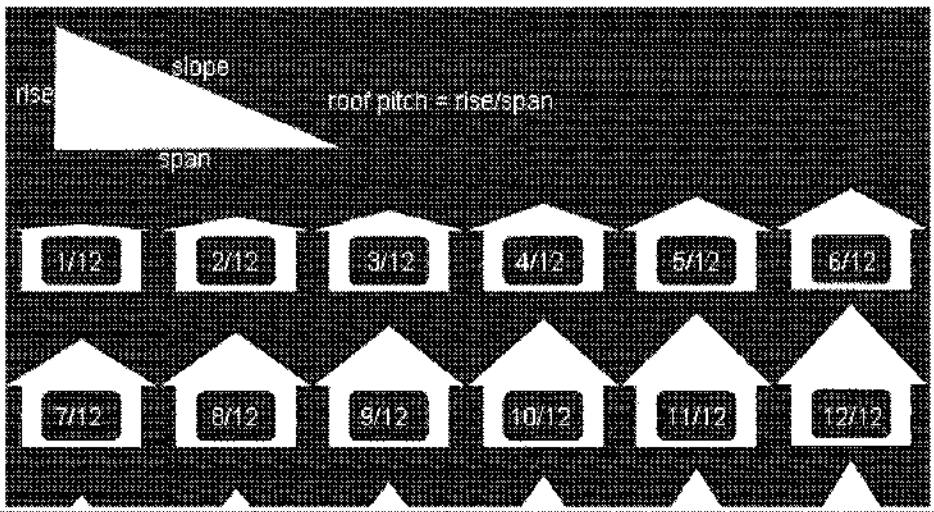
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The area we give out is estimation only. If the roof of your house has complex shape like the one in the right, the most accurate way is to measure all the dimensions and add the areas of all surfaces. You can use our area calculator to calculate the area of each surface. The most common roof materials in the United States are shingles, membrane roofing, ceramic tile, etc. Typically shingle roofs have a life expectancy of 15 to 30 year. Membrane roofing normally can last 5-15 years. Ceramic tile roof is expensive, yet it has a life of more than 100 years.



Roof Pitch

By definition, the roof pitch is the vertical rise divided by the horizontal span



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Roofing Calculator

Use the following tools to estimate the area and the materials needed for the roof. The "House Base Area" is the area of the land the house covers. When measuring, be sure to include the eaves covered areas. Our area calculator can be used to estimate the area coverage of the house. If the house is irregular in shape, you can divide the house covered area into a few simple shapes and add their area together. The roof pitch defines the steepness of the roof. It can be measured or can be estimated via by comparing your roof with our images.

Roofing Area Calculator

House Base Area [ ] square foot

Roof Pitch 1/12 2

Calculate

Roofing Material Calculator

Roof Area [ ] square foot

Calculate

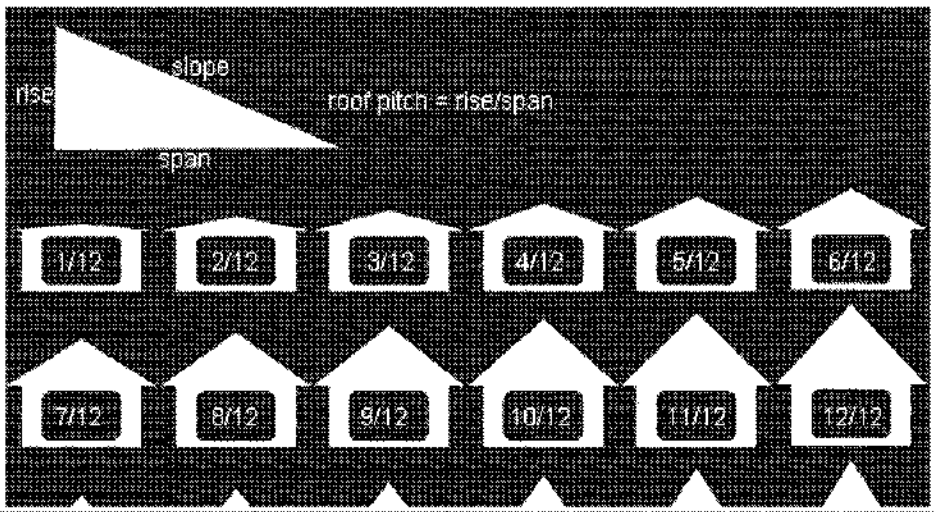
References:

The area we give out is estimation only. If the roof of your house has complex shape like the one in the right, the most accurate way is to measure all the dimensions and add the areas of all surfaces. You can use our area calculator to calculate the area of each surface. The most common roof materials in the United States are shingles, membrane roofing, ceramic tile, etc. Typically shingle roofs have a life expectancy of 15 to 30 year. Membrane roofing normally can last 5-15 years. Ceramic tile roof is expensive, yet it has a life of more than 100 years.



Roof Pitch

By definition, the roof pitch is the vertical rise divided by the horizontal span



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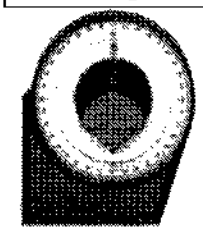
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Roof Pitch, how much to add



This roof pitch table displays a multiplier for adding for different roof pitches

How to find your roof pitch

If you know the pitch of a roof, you can use the numbers in the following pitch table to do the following:

Determine how many square feet of roof area a building has by measuring from the ground.

Determine how many square feet of roof area a building has by measuring blueprints or plans.

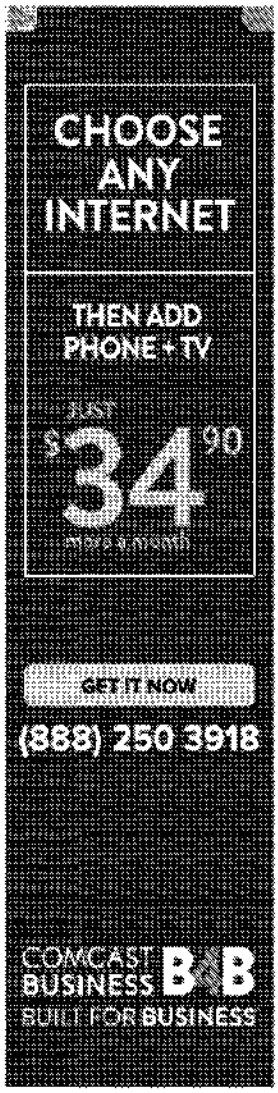
This Roof Pitch Chart will give you your multiplier

Or just enter your numbers into this Roof Pitch Calculator

Roof Pitch	Roof Pitch Multiplier
2/12	1.01
3/12	1.03
4/12	1.05
5/12	1.08
6/12	1.12
7/12	1.16
8/12	1.20
9/12	1.25
10/12	1.30
12/12	1.41
14/12	1.54
16/12	1.67
18/12	1.80
20/12	1.94
22/12	2.09
24/12	2.24

Example:

Roof is 6/12 pitch and measures at 2,400 square feet



roofgenius.com/Roof-Pitch-Calculator.asp

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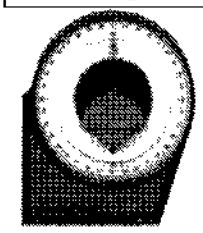
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- Amount to add for pitch
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Popular Roof Materials

This article covers the positive and negative features of the following roofing materials.

- Composition Shingles
- Wood shakes
- Clay Tile
- Slate
- Concrete Tile
- Metal
- Hot Mop



Roofing Tools here

Roof Pitch Calculator Why ?

(Also referred to as roof slope or roof angle)
Adding for roof pitch is needed if you are measuring your roof from the ground or measuring roof blueprints

You can determine how many squares you will need by the square footage of floor plans by adding overhangs,and porches (single stories only, no basements) Although this method is not real accurate

Determine how much roofing you need by using this pitch calculator in 2 easy steps
1. Enter your roofing square feet
2. Select your roof pitch

(Valid entries 100 to 90,000)

Input roof measurements

* Required

Select Your Roof Pitch

Select Pitch

* Required

Select Pitch

Reset

Multiplier	Feet added for pitch	Total	Total Squares
Na	Na	Na	Na

Example:
Your roof area is 3500 sq feet Your Roof Pitch is 6/12 pitch
Your Output
Multiplier 0.12
Feet added for pitch = Multiplier x 3500 = 420 sq feet
Total = 3500 + 20 = 3920
Total Squares = 3920 / 100 = 339.20 squares

Roof Pitch Related

- How to determine roof pitch
- Roof Pitch Visual Examples
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Roof Pitch Calculator



The Roof Pitch Calculator tools below will help you calculate the slope from every possible angle. Each tool performs a specific operation that involves measuring and calculating the slope.

Using this Pitch Calculator(s), you can calculate slope, area, rafter length and other dimensions, and convert Pitch to Degrees (at the bottom). We will explain how to measure roof pitch, using simple tools.

1) Calculate Slope based on Rafters Length:

Roof Span:	24	ft.	0	in.
Roof Rise:	8	ft.	0	in.

Calculate

Roof Pitch = / 12"

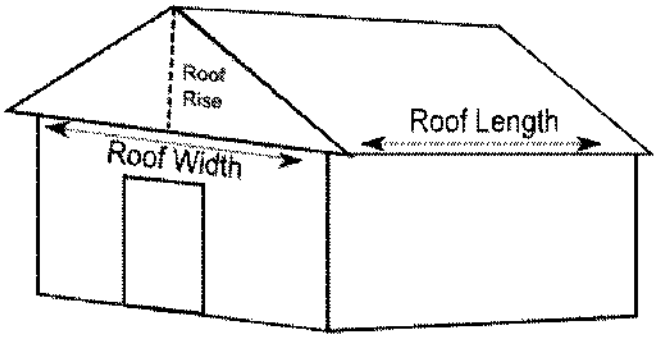


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www.roofcalc.org/roof-pitch-calculator/
Apps

How to use Roof Pitch Calculator:

To estimate roof area, enter width and length (as shown in the measuring diagram below), and either Rise or Pitch - second value will auto-calculate. Click calculate. The results will pop below the calculate button, and will include: Rafter Length, Total Size / Area, and Pitch.

The approximate roof replacement prices above are calculated assuming removal of 1 layer of old shingles, 1 chimney flashing, ridge vent and Ice & Water Shield installation, for both 30 years shingles, and metal roof options. If you want a more accurate price estimate, use our cost estimator tool



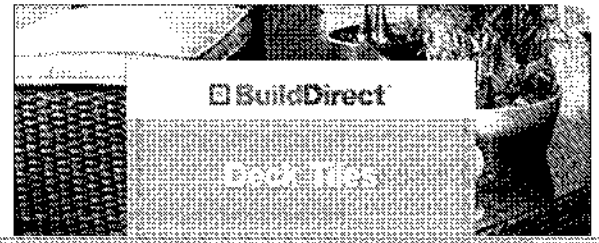
Using the diagram below, measure your roof from the ground, and enter building dimensions into the calculator #2 above. Enter the span (also known as gable side width), and the rise above the base line.

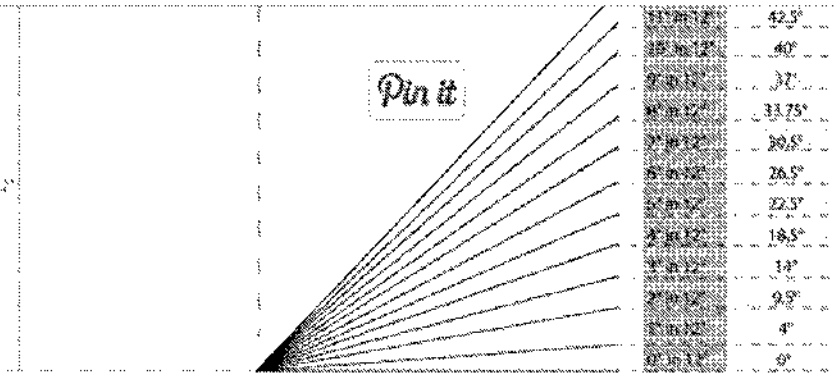
To calculate your pitch and size, measure your roof and plug in your measurements in accordance with the diagram below. Enter EITHER Roof Rise or Roof Pitch.

2) Pitch to Angle (Degrees) Calculator - enter pitch in the first box - calculation is automatic.

Enter Roof Pitch: / 12"

Results: degrees angle





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Asphalt Shingles Calculator – estimate cost of materials, using our tool here.

How Much Does a New Roof Cost?
Get Instant Price Quote

Roof Size:	1500 Sq. Ft.
Roofing Material:	Asphalt Shingles
Remove Old Roof:	YES - 1 layer
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Written by: Alex – the Roofing Wiz

Alex is passionate about Green Building, Metal Roofing, and Loves Ballroom Dancing!

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estimate roof area from "average pitch"

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Mar 4, 2014 - A method needs to be determined to **estimate** the potential roof square footage ... I'm going to use 1.5 so that the eventual usable **roof area** is not inflated. ... Additionally, the **average pitch** is 4/12, the industry standard and I will ...

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Prices vary depending on manufacturer, **length** of warranty, and type of shingle. What types of ... A house with average size, **average pitch** and few complexities can be done in 1-2 days. A house ... What is included in an **estimate** for a **roof**?

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ESTIMATE INSTRUCTIONS. 1.) Square ... Just **figure** the **length** of the room by the width. Do not count ... If your **roof** is multi-pitch just enter an **average pitch**. 4.

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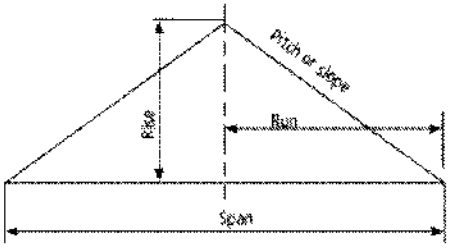
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Roofr Exhibit 1002, Page 788

A) Roof Pitch and Slope

Figure 2
Pitch and slope relationships



The degree of incline a roof possesses is usually expressed as its "pitch" or "slope." Pitch is the ratio of the rise of the roof to the span of the roof. (See Figure 2.) Slope is the ratio of rise in inches to horizontal run in feet (run equals half the span). For example, if the span of a roof is 24' and the rise is 8', the pitch is 8/24 or 1/3. Expressed as a slope, the same roof is said to rise 8" per foot of horizontal run [Slope (inches per foot) = Rise (in inches) / Run (in feet)]. If the rise of the same roof span were 6', the pitch would be ¼ and its slope would be 6" per foot of run. Whether a particular roof incline is expressed in pitch or slope, the results of area calculations will be the same.

It is not necessary to go onto a roof to measure pitch or slope. It can be closely approximated from the ground with the aid of a pitch card (available from many manufacturers) or a carpenter's folding rule as follows:

Stand away from the building and form the rule into a triangle with the 6" joint at the apex and the 12" joint at one side of the horizontal base line. Holding the rule at arm's length, line up the sides of the triangle with the roof as shown in Figure 3, being sure to keep the base of the triangle horizontal. Then, with the zero point of the rule aligned with the center of the base, read the intersection of the zero point with the base. In the example shown in Figure 3, this occurs at the 22" mark. Next, locate the "rule reading" in Figure 4 nearest to the one read in the field and directly under it read the pitch and slope of the roof. For the example, the slope as 8" per foot.

Figure 3
Use of carpenter's folding rule to determine pitch and slope

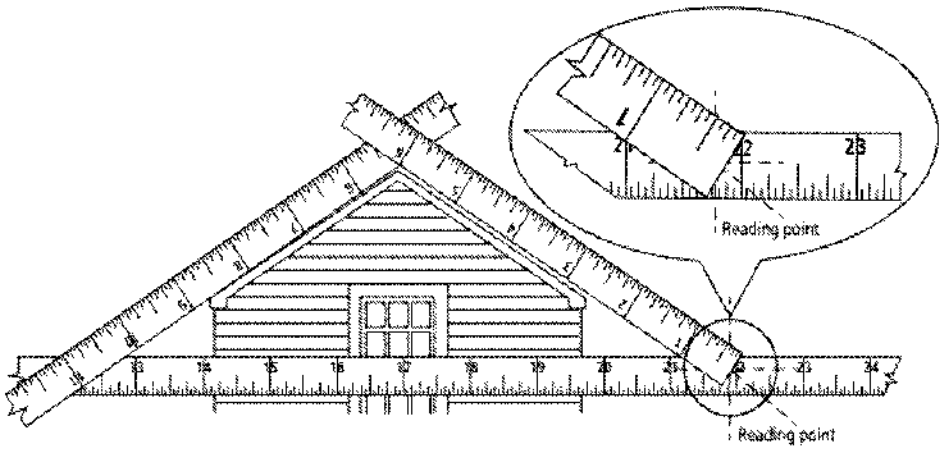
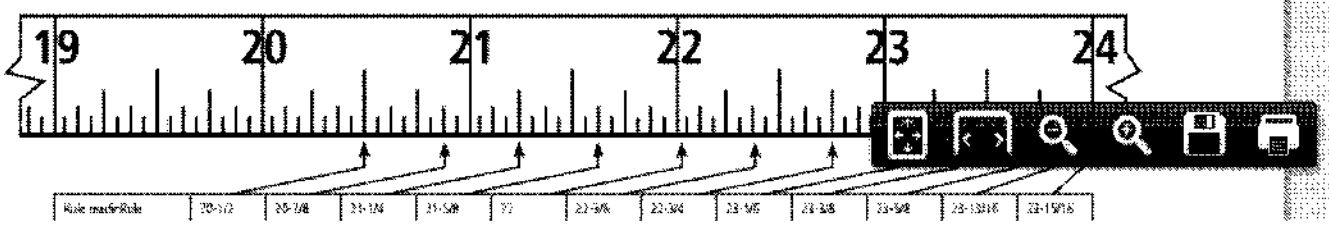


Figure 4
Reading point conversions to pitch and slope



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Method and system for quick square roof reporting

WO 2013142406 A1

Publication number	WO2013142406 A1
Publication type	Application
Application number	PCT/US2013/032760
Publication date	Sep 26, 2013
Filing date	Mar 18, 2013
Priority date ⓘ	Mar 19, 2012
Also published as	US20130246204
Inventors	Chris T. THORNBERRY, Dale R. THORNBERRY
Applicant	Pictometry International Corp.
Export Citation	BiBTeX, EndNote, RefMan

Patent Citations (6), Classifications (2), Legal Events (2)

External Links: Patentscope, Espacenet

ABSTRACT

A set of instructions stored on one or more computer readable medium for running on one or more computer systems is described herein. The set of instructions generally may include instructions for identifying a geographic location of a roof, instructions for determining contact information of one or more contractors within a region of interest of the geographic location of the roof, instructions for determining a footprint of the roof, instructions for determining predominant pitch of the roof, and/or instructions for determining an estimated roofing area based on the predominant pitch and the footprint of the roof

DESCRIPTION (OCR text may contain errors)

Electronically Transmitted: 2013 March 18

A Method and System for Quick Square Roof Reporting Cross-Reference to Related Applications [0001] Not Applicable.

Background

[0002] Residential and/or commercial property owners approaching a major roofing project may be unsure of the amount of material needed and/or the next step in completing the project. Generally, such owners contact one or more contractors for a site visit. Each contractor must physically be present at the site of the structure in order to make a determination on material needs and/or time The time and energy for providing such an estimate becomes laborious and may be affected by contractor timing, weather, contractor education, and the like. Estimates may be varied even between contractors in determination of estimated square footage causing variance in supply ordering as well. Additionally, measuring an actual roof may be costly and potentially hazardous - especially with steeply pitched roofs. Completion of a proposed roofing project may depend on ease in obtaining a simplified roofing estimate and/or obtaining reputable contractors for the roofing project

[0003] Images are currently being used to measure objects and structures within the images, as well as to be able to determine geographic locations of points within the image when preparing estimates for a variety of construction projects, such as roadwork, concrete work, and roofing. Estimating construction projects using software may increase speed at which an estimate can be

CLAIMS (OCR text may contain errors)

What is claimed is:

1. A set of instructions stored on one or more computer readable for running on one or more computer systems, comprising:

instructions for identifying a geographic location of a roof;

instructions for determining contact information of one or more cc within a region of interest of the geographic location of the roof; a

instructions for determining a footprint of the roof,

instructions for determining predominant pitch of the roof;

instructions for determining an estimated roofing area based on tl predominant pitch and the footprint of the roof.

2. The set of instructions of claim 1 , further comprising instructio providing a roof report, wherein the roof report includes one or m images of the roof, one or more oblique images of the roof, the e roofing area and contact information of one or more contractor wi region of interest of the geographic location of the roof.

3. The set of instructions of claim 2, wherein the roof report incluc contact information of the customer.

4. The set of instructions of claim 1 , wherein the one or more cor

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ESTIMATE INSTRUCTIONS

1.) Square footage is the amount of floor space you have under a roof inside or outside of your house. Just figure the length of the room by the width. Do not count multiple floors.

2.) Enter the number of layers you have that need to be removed, or enter 0 if you would like to install a new roof over the existing. Note most cities allow only two layers.

3.) The steepness of the roof is determined by the amount of rise in relation to the amount of run and is expressed in terms as 4/12 pitch, 6/12 pitch etc. Click here to see a diagram to help figure the pitch of your roof. If your roof is multi-pitch just enter an average pitch.

4.) How close can we get a dumpster to the house? On a scale of 1-5 , 1. being very close in the driveway next to the house, 5. being out in the street far from the house. This number indicates the degree of difficulty in cleaning the job-site.

5.)"Starts" are the number of times the shingles will have to be installed on another section of roof that is not in a straight contiguous line with the previous "start". A two sided gable roof with no valleys or dormers has 2 "starts". Click here for help.

6.) "Duration" architectural shingles are installed on about 95% of the homes we roof. Click here

7.) Vents are usually installed at a rate of 1 per 300 square feet of attic floor space. Click here for more info on all vent types.

8.) Many older homes have 3/8 inch plywood and really should have all new sheathing installed. Many of the real old homes (80 plus years old) have wood shingles and spaced 1 x 6 deck boards. These homes must have new sheathing installed to span the spaces in the deck boards.

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estimate roof area from "average pitch"

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For **roofs** with unequal pitches use the **average pitch**. When up to 50% of the **roof space** is developed, add 4 Bracing Bu/m2 to the values in Tables 5.8 to.

How Much Does a New Roof Cost? - home improvement
sacramentohomeimprovement.weebly.com/.../**roofing**-contractors-in-sacr... ▾
Nov 9, 2011 - tCosts below are **estimated** for a new medium-pitch **roof** on a 2400 sq ft. ... Professional installation for an **average pitch roof** may cost around .

What Homeowners Should Know About Attic Ventilation ...
www.parametersconstruction.com/things-we-like-blog.html?entry... ▾
Sep 12, 2012 - To **determine** this, you must first know the square footage (**area**) of your attic. ... Using our example above with an average attic and **average pitch**, ... (Note: if your **roof** pitch is 7/12 to 10/12, add about 20% to your **calculation**:

a guide from start to finish - Entegra Roof Tile
www.entegra.com/information/tile.../a-guide-from-start-to-finish.html ▾
The **average pitch** on a home is 4/12, meaning that for every 4" in vertical rise, there are ... to fit your project, please contact us for a list of contractors in your **area**. ... 3-4 weeks, but we recommend calling for current **estimated** production dates.

The Issaquah Press April 22, 1987 Page16
isq.stparchive.com/Archive/ISQ/ISQ04221987p16.php ▾
Apr 22, 1987 - The loss was **estimated** at $300 ... 2,000 sq. ft. of **average pitch** FREE **ROOF** INSPECTION AND **ESTIMATES** ! For long term **roof** protection and ...

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of Practises for Drainage of **Roofs** and Paved **Areas** – Formerly CP 308) ... The flow chart opposite shows the required steps to **calculate** the **roof** load. This **roof** ...

Council wants more control of height in Ocean City Homes ...
www.shorenewstoday.com › Shore News Today › News ▾
Feb 16, 2014 - Ping said the **average pitch** of the **roof** on most of the houses in ... to the allowable height of buildings in the Ocean City Homes **area**, she said.

Village of East Hampton, NY ZONING - eCode360
ecode360.com/8384891 ▾
By way of example, the replacement of a **roof** or windows or doors in place and ... In all other districts, that percentage of lot **area** covered by the ground floor of all ... . Diagrams illustrating the method of **calculation** are included at the end of this ... a shallow pitch to arrive at an **average pitch**); however, the pitch of a conical. ...

Framing Material Estimate - Building & Construction - DIY ...

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Rollover far side **roof** strength test and simulation
T Chen, EC Chirwa, M Mao . - International Journal of ..., 2007 - Taylor & Francis
... As a consequence, the **estimate** that 75% of the cases had major damage to the far side of the **roof** is conservative. ... In this test rig, load normal to the load platen and the rotation angle of the plate are needed to **calculate** the energy ... **Figure** 28 **Roof** crush simulation model. ...
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M La Gennusa, G Lascari, G Rizzo, G Scaccianoce... - Energy Policy, 2011 - Elsevier
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... The results bear out the slaters' own **estimates** that: (a) a slater's 'thousand' (= 840 slates), also known as a 'heap', should be ... ft is **estimated** to weigh II S6lb., orjust over half a ton; reasonably close to the slater's allowance. ... ft were counted, and near-**estimate** results obtained ...
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... be able to determine geographic locations of points within the image when preparing **estimates** for a ... a request for contractor information and/or a bid request for **estimate** costs and ... The **estimated area** detail 206 may provide the total **estimated roof area** as determined using the ...
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... Simulating the site by means of numerical Simulation , the mined-out **area** will be restored. ... 3 **Roof** Mudstone 35.1 1.5 Low~Mid Level Firmness ... model According to the above information of Laokengkou coal mine of Maozequ, the basic model was established shown in **Figure** 1 ...
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... In the drawing already mentioned, **Figure** 1 is ... By the use of pitch prepared under my in vention, it will not be necessary for the **roof** ing contractor to cart ... are of a pre cise spacing which has been

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scholar.google.com/scholar?q=%2Bestimate+%2Broof+%2Barea+%2B"average+pitch"&btnG=&hl=en&

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Google +estimate +roof +area +"average pitch"

Scholar About 87 results (0.09 sec) Any time

Rollover far side **roof** strength test and simulation

T Chen, EC Chirwa, M Mao .. - International Journal of ..., 2007 - Taylor & Francis

... connections. As a consequence, the **estimate** that 75% of the cases had major damage to the far side of the **roof** is conservative. ... side. The most deformed **area** was **roof** rail, A-pillar, B-pillar and front **roof** rail or header rail. A ...

Cited by 15 Related articles All 2 versions Cite Save

Collyweston Stone Slating Techniques

HB Sharp - Folk life, 1980 - maneyonline.com

... Example 1 A small pent-**roof** of **area** 100 sq. ft. ... is correspondingly just over the slater's 2240 lb. These two examples carefully worked from a small **roof** and a large one, with reliable average weighings, demonstrate the validity of the slater's **estimate** based on centuries of ...

All 3 versions Cite Save

Method and System for Quick Square **Roof** Reporting

CT Thornberry, DR Thornberry - US Patent App. 13/424,054, 2012 - Google Patents

... report includes one or more ortho images of the **roof**, one or more oblique images of the **roof**, the estimated roofing **area** and contact ... The time and energy for providing such an **estimate** becomes laborious and may be affected by contractor timing, weather, contractor ...

All 2 versions Cite Save

Structural geology of the Knife Lake **area** of northeastern Minnesota

JW GRUNER, CE Dutton ... - Geological Society of ..., 1941 - gsabulletin.gsapubs.org

... 82. PP. 1577-1042. 5 PLS. 5 FIGS. OCTOBER 1, 1941 STRUCTURAL GEOLOGY OF THE KNIFE LAKE **AREA** OF NORTHEASTERN MINNESOTA BY JOHN W. GKUNER ... 1614 (1577) Page 3 1578 JW GRÜNER----GEOLOGY OF KNIFE LAKE **AREA** Page ...

Cited by 48 Related articles All 2 versions Cite Save More

A model for predicting the potential diffusion of solar energy systems in complex urban environments

M La Gennusa, G Lascari, G Rizzo, G Scaccianoce... - Energy Policy, 2011 - Elsevier

... ArcView® GIS, 1996a and ArcView® GIS, 1996b) is applied to the GRID, that allows to **estimate** the size ... The effective extension of the **area** of surfaces with flat coverings is directly obtainable from urban planimetry ... Main characteristics of the **roof** buildings of the town of Palermo. ...

Cited by 19 Related articles All 9 versions Cite Save

Prosody as a marker of information flow in spoken discourse

M Swerts, R Geluykens - Language and speech, 1994 - las.sagepub.com

... a more global level, speakers appear to use relative height of pitch peaks and of **average pitch** values as ... an independent theory of topic-structure is formulated, much of our argument in this **area** is in ... of a house from a set of ready- made pieces of cardboard (eg, a **roof**, a front ...

Cited by 146 Related articles All 4 versions Cite Save

Do voice recordings reveal whether a person is intoxicated? A case study

nih.gov [HTML]

K Johnson, DB Pisoni, RH Bernacki - Phonetica, 1990 - karger.com

... If the tongue tip is kept close to the front teeth and the constriction at the **roof** of the ... provide a good example of the conceptual distinctions which need to be maintained in this **area**, although they ... We **estimate** that the signal-to-noise ratio in these samples ranges from 5 to 10 dB. ...

Cited by 50 Related articles All 8 versions Cite Save

Female-pitched sound-producing voice prostheses--initial experimental and clinical results

researchgate.net [PDF]

M Van der Torn, IM Verdonck-de Leeuw... - European archives of ..., 2001 - Springer

... fundamental frequency, we also estimated the 10%– 90% interquantile F0 range to **estimate** the intonation ... Sound-producing modules with a small cross-section **area** (SPVP-2S and 2L) have

+roof +area +"average pi

scholar.google.com/scholar?q=%2Broof+%2Barea+%20"average+pitch"&btnG=&hl=en&as_sdt=0%2C

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Google +roof +area +"average pitch"

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Rollover far side **roof** strength test and simulation
T Chen, EC Chirwa, M Mao .. - International Journal of ..., 2007 - Taylor & Francis
... **average pitch** angle was 6 · where the test specimen body- in-white was fixed securely on a base frame at a pitch angle (longitudinal angle) of 6 · above the horizontal plane (Figure 22). ... The most deformed **area** was **roof** rail, A-pillar, B-pillar and front **roof** rail or header rail ...
Cited by 15 Related articles All 2 versions Cite Save

Vehicle **roof** with a series of raisable cover strips
W Salz - US Patent 5,836,642, 1998 - Google Patents
... This increase is especially pronounced on roughly the last tenth of the crank path, so that the **average pitch** there is greater than on the corresponding path ... In the **area** of the rear end of the guide rail 75, there is a counterpiece 51 which is fixed to the **roof** (this stationary ...
Cited by 10 Related articles All 2 versions Cite Save

[PDF] ... STUDY OF RELATIONSHIP BETWEEN URBAN STRUCTURE AND AMBIENT MICROCLIMATE IN NEW DEVELOPED HOUSING **AREA** IN JOHOR, MALAYSIA utm.my [PDF]
K Saito, I Said, MH Rasidi, M Shinozaki - epublication.fab.utm.my
... This particular number of distance is derived from **average pitch** of building (5.76m) and a ... more deeply consideration about impact to surrounding environment in the housing **area** from differences ... Albedo: Soil (0), Concrete (0.4), Asphalt (0.2) 3) Albedo: Wall (0.25), **Roof** (0.3) 4 ...
Cited by 1 Related articles Cite Save More

A COBPOBATION OF googleapis.com [PDF]
SO PITCH - US Patent 1,088,635, 1914 - Google Patents
... An **average pitch** barrel and its contents weigh at an average 550 lbs, making it both a ... of pitch prepared under my in vention it will not be necessary for the **roof** ing contractor to ... which has been determined by actual experiment, and are of relatively small **area** with comparatively ...
Cited by 8 Related articles Cite Save

Roof scaffold
CJF Courchesne, TR Palmer - US Patent 4,957,186, 1990 - Google Patents
... extension leg 10 is provided with a pad 26 distributing the force over an **area** of the ... work is necessary since the cleat has in no way interfered with the installation of the **roof**. ... member 13 should be such that the plank 14 is substantially perpendicular to the **average pitch** of **roof**. ...
Cited by 36 Related articles All 2 versions Cite Save

[CITATION] Deep coal mining in Springhill No. 2 Mine
WF CAMPBELL - Min. Eng.(New York), 1958
Cited by 2 Related articles Cite Save

Collyweston Stone Slating Techniques
HB Sharp - Folk life, 1980 - maneyonline.com
... unusually low one (38°), though the essential practice differs not at all from that in the **average pitch** for this **area** (48°). The **average pitch** for thatch is 54 ... **Roof** details . (alater retimbering): one tie beam (6inches by 4 inches) to wall plates (4inches by 1 1/2 inches) and to the centre ...
All 3 versions Cite Save

Method and System for Quick Square **Roof** Reporting
CT Thornberry, DR Thornberry - US Patent App. 13/424,054, 2012 - Google Patents
... based on the plurality of pitch values. 11. The set of instructions of claim 10 , wherein each pitch value is associated with an estimated percentage of **roof area** to provide an **average pitch** value. 12. The set of instructions of claim ...
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Roof inspection systems with autonomous guidance

+roof +area +"average pi

https://www.google.com/search?q=%2Broof+%2Barea+%26"average+pitch"&oq=%2Broof+%2Barea+"

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Results for **+roof +area +average pitch** (without quotes):

Roof pitch - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/**Roof_pitch** Wikipedia

Some types of stone **roofs** have a very restrictive **roof pitch**, too low a **pitch** . Thus, **pitch** is typically greater in **areas** of high rain or snowfall. . The high, steeply-**pitched** gabled **roofs** of northern Europe are **typical** in regions of heavy snowfall.

Description - Historical pitches - See also - References

You visited this page on 11/20/14.

Roof Pitch » Roof Pitch Calculator - APB Pole Barns

www.pole-barn.info/**roof-pitch**.html

Find out how to calculate **roof pitch** on an existing **roof**. Use our **roof pitch** calculator to convert the **roof** angle to **pitch** if using an angle finder . . 3/12 **typical** in southern climates 14.04° 2/12 - low **roof pitch** . **Length**. Rafter **Length** Calculator.

How Do You Calculate Square Footage for a Roof? | Home ...

homeguides.sfgate.com › Construction & Remodeling › Square Footage

.. one of the first steps you may perform is figuring out the **roof area**. Both the **roof area** and **pitch** contribute to the cost of a roofing job. Calculate square footage .

What defined the pitch of the average house roof? - The Nake...

www.thenakedscientists.com › ... › Non Life Sciences › Technology

Oct 19, 2010 - 18 posts - 4 authors

Area rules and may determine building design and permits. Ideally you ... Anther common approach is to use a metal **roof** with a steep **pitch**.

How to Determine Roof Pitch

www.carpentry-pro-framer.com/**roof-pitch**.html

Determining **roof pitch** is a rather simple process if you use one of these five techniques. . Keeping the level tight to the **roof surface**, the tongue of the framing square. ... These **roofs** can be walked safely by an **average** person and require no ...

Roof Pitch Calculator | RoofCalc.org

www.**roof**calc.org/**roof-pitch**-calculator/

The Roof Pitch Calculator tools below will help you calculate the slope from every ... To estimate **roof area** enter width and **length** (as shown in the measuring .. you can accurately estimate the rise by measuring 3 spans of siding (**typical** vinyl ..

Roofing Calculator

www.calculator.net › Other Calculators

Roof Pitch - How To Figure

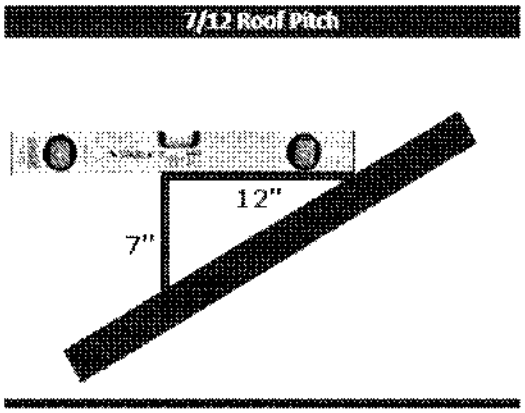
Roof pitch refers to the amount of rise a roof has compared to the horizontal measurement of the roof called the run.

To see how pitch impacts the look of a garage and changes cost click the design center button on our **pole barn kits** page.

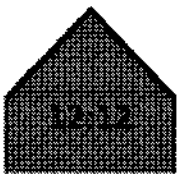
The picture below shows the pitch of a 7-12 roof slope meaning that for 12" of horizontal measurement (roof run) the vertical measurement (roof rise) is 7".

Construction Calculators & Charts
DIY pole barn kits
Cubic Yard Calculator
Roof Pitch Calculator
Truss Calculator
Rafter Calculator
Squaring Building Lines Example

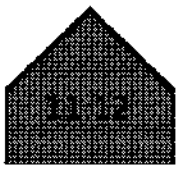
This measurement is best done on a bare roof because curled up roofing shingles will impair your measurement. If this isn't practical then perform the same measurement on the underside of the roof. We included a roof pitch chart below the 7-12 example image and the calculator below that.



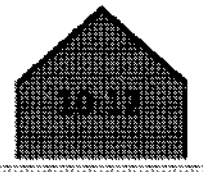
Roof Pitches



12/12 pitch angle 45°

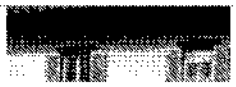


11/12 angle 42.51°



10/12 angle 39.81°

Roof Pitch Table	
1 12	4.76°
2 12	9.46°
3 12	14.04°
4 12	18.43°
5 12	22.62°
6 12	26.57°
7 12	30.26°
8 12	33.69°
9 12	36.87°
10 12	39.81°
11 12	42.51°
12 12	45°



How to Measure a Roof From the Ground

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3 Estimate the pitch of the roof. Roofs have one of three pitches: low, medium or high. A low pitch rises 3 inches every 12 inches of base horizontal length. A medium pitch rises 6 to 9 inches every 12 inches of base horizontal length. A high pitch roof rises more than 9 inches for every 12 inches of base horizontal length. Estimate the roof pitch by sight or calculate it with a level in the next step.

4 Calculate roof pitch by climbing a ladder up to the point where the roof begins. Hold the level horizontally so that the end of the level touches the roof about 12 inches above the bottom of the roof. Find the 12-inch point on the level and measure straight down to the roof using a tape measure. Note the measurement; less than 6 inches is a low pitch, 6 to 9 inches is a medium pitch and more than 9 inches is a high pitch.

5 Multiply the number of roofing squares for a low-pitch roof by 1.06 to 1.08 to get the square roof area. Multiply the number of roofing squares for a medium-pitch roof by 1.12 to 1.25 -- or by 1.3 to 1.42 for a high-pitch roof -- to get the square roof area.

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Stay Cool & Comfortable This Summer With AC Sizing Costs For Your Home! remodelrepairreplace.com/AC_Sizing

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Construction Estimate
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Boost Testosterone 40+
One fast and easy way to boost your body's free testosterone www.nugenix.com

Things You Will Need

- Steel tape measure
- Level
- Ladder

References (1) >

About the Author

Kathryn Hatter is a veteran home-school educator and regular contributor to "Natural News." She is an accomplished gardener, seamstress, quilter, crocheter, painter, cook, decorator and digital graphics creator and she enjoys technical and computer gadgets. Hatter's Internet publications specialize in natural health and she plans to continue her formal education in the health field, focusing on nursing.

www.newenglandmetalroof.com/roofing-estimator-guide.html

Apps

installation cost, which is 20 times 300, which equals to $6,000.0

slope 1 of 13

Finally, we add results, $3,000 + $6,000 = $9,000 total for the tear off and installation of a new asphalt shingle roof.

Having read and practiced the steps outlined in this Do it yourself roof estimating guide, and learning the practical steps of how to measure your roof, you should now have a better understanding about your own roof, be able to figure out its approximate actual size in roofing squares, and define the level of difficulty involved in the roof replacement. I firmly believe that knowing these easy skills is going to provide more benefits for you, than some roof calculator software spitting the mystical numbers at you.

I wish you best of luck in getting a great quality roof at a fair price!

Legal Disclaimer:

The roofing multiplier figures provided in this post are not meant to be interpreted as the absolute accurate measures, but rather they are just some mere guess-estimate values, that were arrived at through author's experience with estimating roofing jobs, and through using the, sometimes, necessery number allowances. There are many highly complex roofs where exact roof calculations may be difficult, or even impassible to perform. As such, all the figures above are to be used for your entertainment purposes only, and to be considered as not particularly reliable. They cannot be considered legally binding, valid, or used in the court of law.

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roofgenius.com/Roof-Pitch-Examples.asp

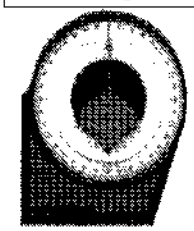
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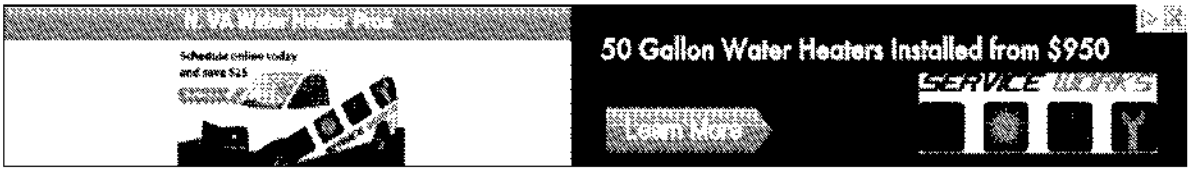
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Pitch and angle finder



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Visual Roof Pitch Examples

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Roof Pitches 4/12 thru 12/12

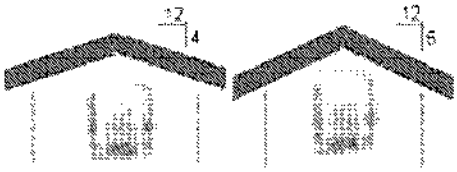
The examples below provide visual examples of roof pitch.

To determine your roof pitch go here.

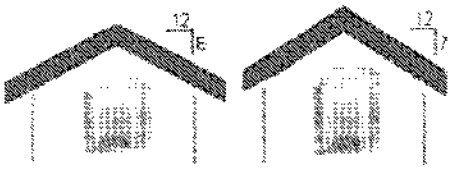
Other terminology for roof pitch are; Roof Slope, Roof Angle and Pitch Degrees.

To see roof pitch to degrees equivalents go here.

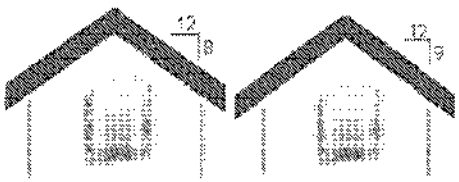
4/12 Pitch 18½° Details 5/12 Pitch 22½° Details



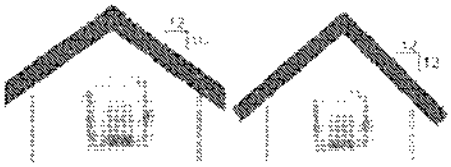
6/12 Pitch 26½° Details 7/12 Pitch 30¼° Details



8/12 Pitch 33¾° Details 9/12 Pitch 37° Details



10/12 Pitch 40° Details 12/12 Pitch 45° Details



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final-analysis.com/calculators/roof_area.htm
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Roof Area Calculator

conversions	
inches	feet
1	.08
2	.17
3	.25
4	.33
5	.42
6	.50
7	.58
8	.67
9	.75
10	.83
11	.92

This calculator will help you determine the amount of square feet you have for replacing roof shingles. Roof shingles are figured by number of squares. 10'x10' = 100sf (1 square)

Roof Area Calculators: GABLE & HIP SHED

For each of the roof types pictured below, **L** = horizontal Length, **W** = horizontal Width, and **H** = vertical Height, all entered **in feet**. Slope **in inches per foot** may substituted for H. (If you do not know how to measure slope, see **these instructions**.)

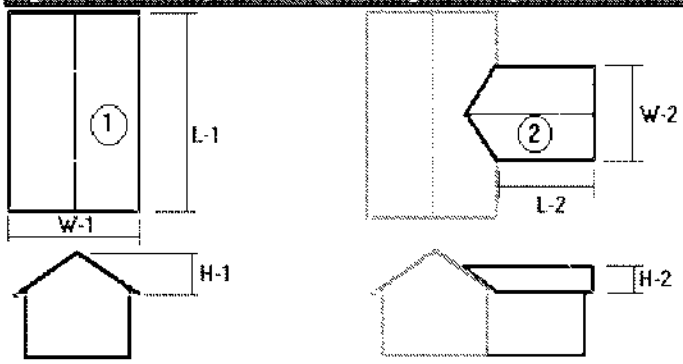
Hip roofs can present a problem for height measurement, and the slope method may be substituted in place of height measurement. Since modern architecture has allowed the incidence of mixed slopes in a single structure, the calculator allows for entry of differing slopes for intersecting roofs.

For many roofs, dimensions can be taken from the ground or from a ladder. Be sure that your measurements include any overhang at the eaves. Height can often be measured at the end wall at the center of a gable.

Complex roofs may have numerous repeats of these shapes - perform a separate calculation for each section, then add the results together (on paper) to obtain total roof area. A "**salt box**" roof with unequal sides may be calculated as two separate shed roof shapes. An "**A-Frame**" roof is simply a gable with high slope.

GABLE OR HIP ROOF:

A gable roof and a hip roof of the same length and slope will have identical areas.



Enter roof dimensions below for your roof **in feet**, (or slope as **inches** rise per foot.)

- If you enter only L-1, W-1, & H-1, the result will be the area of a single straight gable roof.
- If you enter all six values, the result will be the actual exposed area of both roofs. You cannot enter values for Area 2 alone.
- The values calculated for roof 1 and roof 2 are independent. The total will not equal their added values, as the calculator subtracts the hidden area from roof 1 at the intersection, and displays only the actual exposed roof area for the total.

CALCULATE

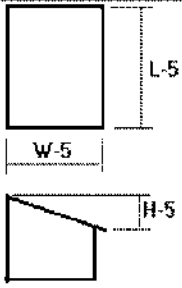
	L-1	W-1	H-1	slope1		Area 1	
	0	0	0	-OR- 0	/12 =	0	ft²
	L-2	W-2	H-2	slope2		Area 2	
	0	0	0	-OR- 0	/12 =	0	ft²

Total Exposed, Areas 1& 2 Combined: 0 ft²

Roof 1 Hidden: 0 ft²

Roof 2 Ridge Length: 0 ft

Shed Roof:



Gather the dimensions for your shed roof, and enter below **in feet**. (or slope as **inches** rise per foot.)

CALCULATE

L-5	W-5	H-5	slope5		Area 5
0	0	0	-OR- 0	/12 =	0 ft²

Back to construction calculators

https://web.archive.org/web/20090412034029/http://support.geoestimator.com/kb/entry/4/

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How do I set pitches on my drawing?

GeoEstimator drawings do not come with actual pitch numbers set, just the downslope direction of the pitch. In order to get the accurate numbers from the drawing the End User needs to input these pitches. The pitches can be set either via the context menu (right-click menu) on the 'Pitch' tab, or the Totals table on either the Pitch or Area tab.

The context menu provides 2 options for setting Pitches: "Set All Pitches", "Set Pitch Direction". The "Set All Pitches" command allows you to input a single number that will be applied to **all** planes on the drawing. The "Set Pitch Direction" brings up a dialog that allows you to set the direction and pitch of a single plane.

When utilizing the Totals tables on either the Pitch or Area tab you can only set the pitch on a per plane basis by selecting the Pitch column for the given plane.

The recommended steps would be the following:

1. Use the 'Set All Pitches" command to set all pitches to the same number.
2. Use either the "Set Pitch Direction" or utilize the Totals table to change the specific planes that differ.

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Views: 117

Posted: 06 Feb. 2009
by: GeoEstimator S.
Updated: 06 Feb. 2009
by: GeoEstimator S.

Setting via the context menu on the Pitch tab.



Setting via the Totals table on the Pitch or Area tab.



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When utilizing the Totals tables on either the Pitch or Area tab you can only set the pitch on a per plane basis by selecting the Pitch column for the given plane.

The recommended steps would be the following:

1. Use the 'Set All Pitches" command to set all pitches to the same number.
2. Use either the "Set Pitch Direction" or utilize the Totals table to change the specific planes that differ.

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Posted: 06 Feb, 2009
by: GeoEstimator S.
Updated: 06 Feb, 2009
by: GeoEstimator S.

Setting via the context menu on the Pitch tab.



Setting via the Totals table on the Pitch or Area tab.



Also read

- How do I set the Reference Measurement for my GeoEstimator Drawing?
- I just received my GeoEstimator Drawing, what do I need to do?

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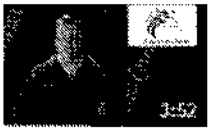
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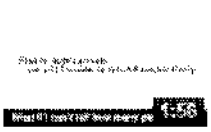
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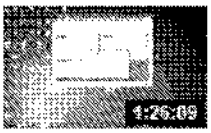
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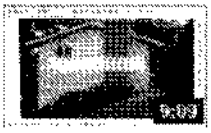
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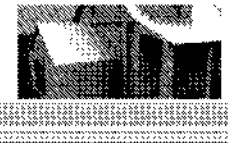
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Ordering & Reading
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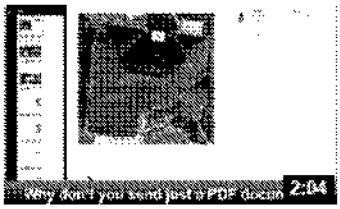
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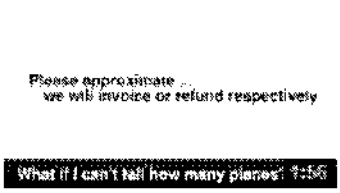
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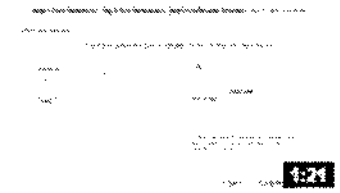
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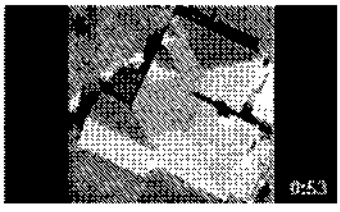
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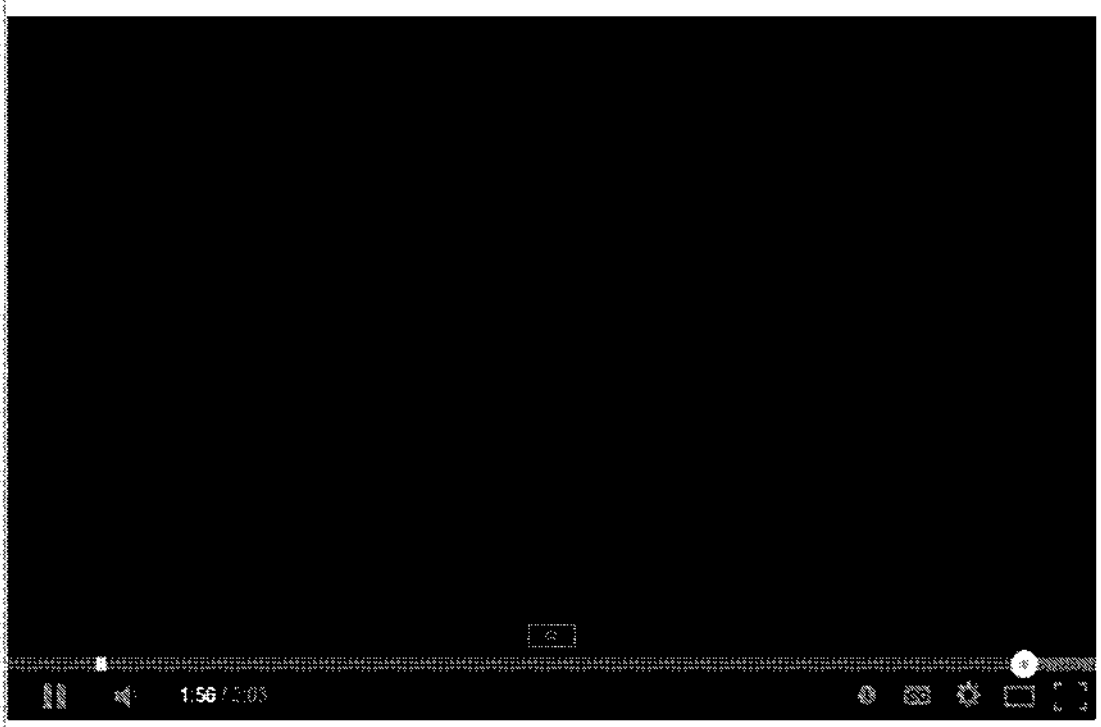
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EagleView VS Traditional Roof Estimating

www.EagleView.com

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Uploaded on Jul 9, 2009

Funny cartoon illustrates the value of EagleViews remote aerial roof estimating versus traditional roof measurements. www.eagleview.com

Music "Bopping Along Main Street" by TVMusic (Google Play • AmazonMP3 • iTunes • eMusic)

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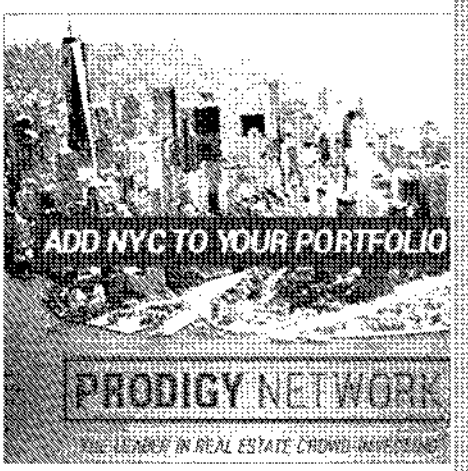
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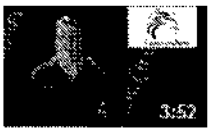
Top comments

Zachary Pattison 1 month ago

Great technology; completely unnecessary on the vast majority of residential roofing projects. You still need a person to do an inspection anyway to determine layers, pitch, sheeting damage, customer wants, problem points, etc. Average roof can be measured in 5 minutes with no middle person and this way I know it's accurate.

Reply





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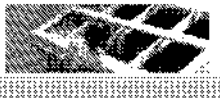
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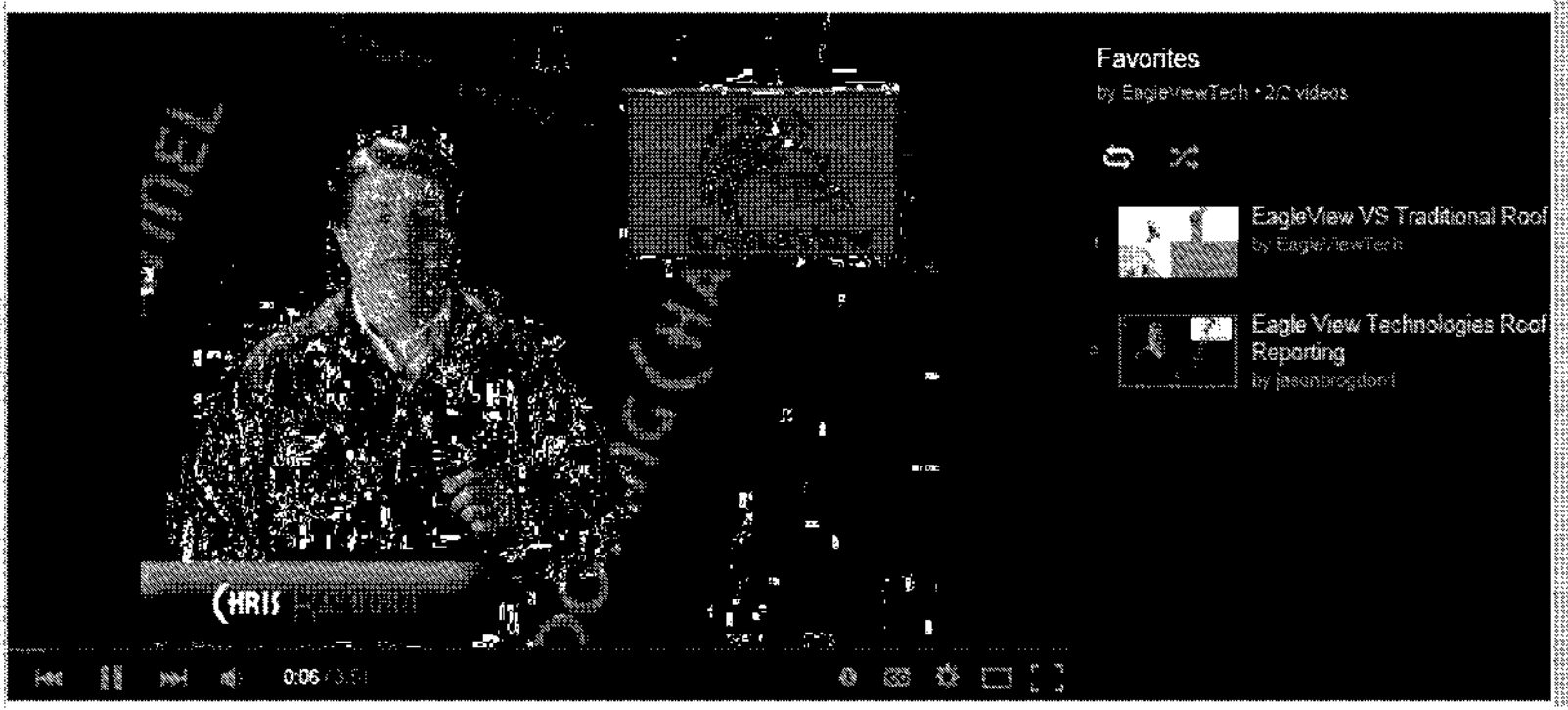
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Eagle View Technologies Roof Estimate Reporting

jasonbrogdon1

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Uploaded on May 9, 2009

This video is a short informative collaboration about the Eagle View reporting system that includes aerial photography, roof pitch, valley and ridge, and total square footage. When you opt to get a report with David Washington (813-786-5424), you will be able to estimate your next project without ever getting out

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Phill R. 4 years ago
If this did not cost so much maybe more people would use it.

Alvin Amadura 4 years ago
EV PHI mabuhay! lol



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Eagle View Technologies Roof Estimate Reporting - YouTube



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May 10, 2009 - Uploaded by jasonbrogdon1
This video is a short informative collaboration about the Eagle View reporting system that includes aerial ...

Eagle View Not Very Accurate IMO - Roofing - Contractor Talk

www.contractortalk.com › Forum › Trade Talk › Roofing
Sep 20, 2011 - 20 posts - 12 authors
There are areas that are flat, 1/12 or 2/12 pitch but according to the report have ... You of course need to count layers of shingles, type of venting, roof slopes etc

Roofing.com • View topic - geoestimator... eagle view... etc etc

www.roofing.com/forum/geoestimator-eagle-view-etc-etc-t9154.html
Feb 28, 2010 - 15 posts - 10 authors
It has all the tools to lay out a roof the way Eagle View and the others do. . . if im gonna measure two lengths on the house, and get the pitch.. i might as well ...

Roofing.com • View topic - Measuring Roofs by Satellite?	13 posts	Oct 4, 2011
Roofing.com • View topic - Pictometry and sales fees	15 posts	Jul 27, 2011
Xactimate / Adjusters / Eagleview - Roofing.com	15 posts	Jul 7, 2011
I use - How To Roof A House, Replace Shingle or Fix a ...	15 posts	Mar 25, 2011

More results from www.roofing.com

EagleView's Software Measures Rooftops With Photos From ...

www.bloomberg.com/.../eagleview-s-software-measures-... Bloomberg L.P.
Dec 8, 2011 - Now they can get the precise dimensions of roofs -- the area of each section, the pitch, the ... EagleView patches together detailed roof renderings using aerial photos . "It's very difficult to get an accurate measurement with a tape measure," he ...

[PDF] EagleView™ Technologies Is Changing the Way ...

www.eagleview.com/Portals/0/. ./RC_Changing_The_Business.pdf
Jul 16, 2010 - unbelievable. We are finding that we can take the EagleView measurements which include square footage, lineal footage and pitch, calculate the waste from the.

[PDF] EagleView Measures Up to Reroof Tampa General Hospital

www.eagleview.com/Portals/0/CaseStudies/EagleView_Measures_Up.pdf
Aug 11, 2010 - roofing decks including square footage, pitch and parapet details. ... "Some people think that the reports are only for estimating but we have found that the ...

EagleView > Products_old > Extended Coverage

www.eagleview.com/Products_old/ExtendedCoverage.aspx
Feb 21, 2012 - MUST be field verified and can be entered manually after verification using our pitch calculator tool; A landscape-format report to easily identify the need fo...

the house. All I need is a picture. Give me an address in CT and one measurement and slope and I will see if I can do it. It is true some areas are hard. When that happens I use pictometry.

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Authentic_Dad | **Post subject:** | **Posted:** Tue Jul 27, 2010 5:48 am

offline

Joined: Thu Jul 23, 2009 4:13 am
Posts: 2315
Images: 14
Post liked: 280 times
Liked posts: 581 times

> **Stormer wrote:**
>
> > **wadman1 wrote:**
> >
> > over here in CT they cant get in close enough to give a good report. any one else having that problem in there state?
>
> I would like to try it. I have developed a way to do it for free with a few free programs. All I need is one measurement on the roof like and eave you can measure from the ground. I do all my siding jobs with one window or door measurement on each side of the house. All I need is a picture. Give me an address in CT and one measurement and slope and I will see if I can do it. It is true some areas are hard. When that happens I use pictometry.

Stormer, would you mind sharing some more detail relating to the free programs you use and the methodology? I'm guessing you use the reference measurement you take for scaling purposes. Even so, there's still a fair amount of work you have to do to get all the measurements and areas on the roof. With a Geoestimator Report running $35 to $55, hard to justify the time expenditure. I guess though if they can't get the satellite image, that doesn't work.

I find if someone can provide me with a decent hand sketched roof diagram, the pitches and ground measurements, I can sketch highly complex roofs in Xactimate and get a very accurate count on the squares, hip/ridge, valleys, etc.. I prefer this to Geoestimator and Eagle View as I believe it to be more accurate. I've found both of those programs work reasonably well for less complex roofs but when you get into multi level roofs with lots of overhang, sidewalls, etc., I find they consistently come up a bit short on the count. They also don't typically cover eyebrows and in some cases, small wings.

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found nothing

So he began experimenting with sites like Microsoft's (**MSFT, Fortune 500**) Bing and Google (**GOOG, Fortune 500**) Earth, searching for satellite images. What he discovered surprised him: aerial photography, rather than satellite imagery, could provide better pictures and more accurate measurements.

"I thought there was certainly a huge opportunity out there," says Pershing, 39.

Pershing studied one of his wife's birdhouses, staring at the roof from different angles. He took snapshots in his head of those angles and then sketched various viewpoints of the roof. Over the next few months, he holed up at his computer on nights and weekends, developing software that would use algorithms to infer the size, shape, pitch and area of the roof.

He practiced his algorithms on a few addresses, including his own and his neighbors'. He even pulled up imagery of pyramids in Egypt, estimating the height of the pyramid to within a couple of bricks. He got the slope of his neighbor's homes almost exactly.

By the end of 2007, Pershing quit his job making software for ultrasound machines and started EagleView in a small rented office outside Seattle. He convinced family and friends to invest $200,000 into his new venture and set out to buy rights to aerial photographs normally used by states, counties and the U.S. Geological Survey.

When Pershing began telling contractors and insurance claims adjustors about his technology, they were skeptical. The industry had for decades measured by hand.

"I thought, 'There is no way,'" says Belz, the Missouri claims adjustor. But once a few big insurers embraced the technology, Belz and others began to follow.

Pershing hired tech veteran Chris Barrow to be CEO in 2008 and changed roles to become chief technology officer. Barrow then raised $6 million from investors.

"One of the smartest things Chris did was step away," says Roger McOmber, an angel investor in Dallas. "It's hard to do, but it's that team mentality."

Today, EagleView customers can order reports online or through a smartphone app and can get a PDF report delivered in an hour. A dozen competitors, including sites like GeoEstimator.com and Roofwalk.com, offer similar services. Despite the competition and the recession, EagleView's sales grew at a 200% clip last year.

Belz, the claims adjustor, says he can process 25% more claims each day without ever sending an adjustor onto a roof -- saving at least 45 minutes per job. "It really speeds the day up for adjustors," he says. "And going onto the roof is one of the most dangerous parts of the job."





The gun range where you can buy booze



2015 Ford Shelby: More than fast



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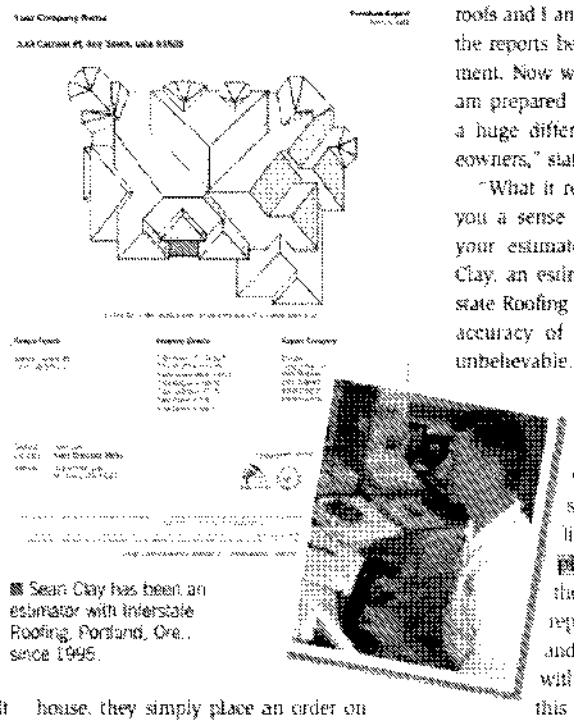
Roofr Exhibit 1002, Page 810

Roofing Contractor

2010 Case Study

EagleView™ Technologies Is Changing the Way Contractors Do Business

Throughout many roofing professionals' careers there has been technology that has literally changed the way they do business. Some are easy to recognize such as fax, cell phone and the Internet while others are very industry-specific such as software for estimating, accounting and production. A new technology that is again changing the course of the roofing industry has been developed and perfected over the last two years by EagleView Technologies out of Bothell, Wash. — aerial roof measurement reports.



Sean Clay has been an estimator with Interstate Roofing, Portland, Ore., since 1996.

For generations, roofing estimators have been climbing ladders and measuring roofs. "Measuring roofs takes time, money and is a huge safety concern for our company," stated Bill Gabel, an estimator for Interstate Roofing of Portland, Ore., since 1994. "It easily adds two hours to estimating for every job that I could be spending on the next estimate." When asked what he has done to change that, he was very definite, "We pull an EagleView report."

Software as a service is the new terminology for what EagleView is providing the roofing industry. "We are in our sixth generation of aerial measurement software technology and improving it every day," stated Chris Barrow, president and CEO of EagleView Technologies. "It is the next revolution in high tech. Instead of roofing contractors spending thousands installing software and maintaining crews in-house, they simply place an order on the Internet for a roof measurement report and they are ready to estimate the job in hours."

Interstate Roofing, one of Portland's largest residential and commercial roofing companies, started out using the EagleView reports on just large and complicated jobs. What they have seen since then is an overall shift in how they do business utilizing the EagleView reports.

"Before I would pull up to a house and see the complexity of the roof and after talking to the homeowner, go back to the office and order an EagleView report. Now I know which neighborhoods have the large cut-up roofs and I am starting to order the reports before my appointment. Now when I show up, I am prepared and it is making a huge difference with homeowners," stated Gabel.

"What it really does is give you a sense of confidence in your estimate," agreed Sean Clay, an estimator with Interstate Roofing since 1995. "The accuracy of these reports is unbelievable. We are finding that we can take the EagleView measurements which include square footage, lineal footage and pitch, calculate the waste from the report's waste table and we are right on with our estimate. In this economy, homeowners want to know that they are getting exactly what they need, no more, no less."

"I have two jobs just recently where I estimated the roofs and then we pulled an EagleView report," confirmed Gabel. "In reviewing the results with production, EagleView was dead on. It is hard for us estimators who have been doing it for a long time to put that much faith in a report but I am consistently finding savings of at least two squares or more in my estimates. In today's competitive economy, two squares can win or lose the job."

For more information, visit www.eagleview.com.

What is your service coverage?

Our service coverage spans over 90% of the populated areas in the United States and several areas in Canada. We are continually working on expanding coverage for all areas in the United States, as well as other regions. Typically, image quality and coverage is greater for highly populated areas, whereas coverage for rural areas can be more limited.

General

How do you determine the [redacted]?

Our proprietary patented software uses advanced image processing techniques to determine the pitch angles from aerial photographs. EagleView's patented measurement technology allows us to accurately determine pitch in order to produce true, complete measurements in multiple dimensions. Because our measurements are generated from 3D diagrams, they maintain the true integrity and accuracy of the structure.

How current are your images?

EagleView uses the most recent, highest resolution image libraries available. Typically, the best available imagery is less than two years old. Areas of higher population growth or susceptibility to catastrophic storms are often photographed more frequently, whereas rural areas may be photographed less frequently.

What is your Accuracy Guarantee?

EagleView Premium and Solar Reports are guaranteed to be more accurate than any other measurement method. If you disagree for any reason, you won't be charged for the report. Each EagleView Premium and Solar report goes through a five-step quality control process which allows us to deliver precision accuracy. Our Accuracy Guarantee is only available on Premium and Solar reports which offer complete measurements, including pitches. All other reports offer our Satisfaction Guarantee. If for any reason you aren't satisfied with your order, we will refund the cost of the report. For questions about our Accuracy Guarantee contact us at customerservice@eagleview.com.

Why do you ask me to move the marker?

When you search for a property, a marker is placed on the map at the address coordinates. Sometimes the marker is positioned in an ambiguous location (such as the middle of a street or field) or there are multiple buildings on the same parcel of land. If this is the case, the marker will need to be re-positioned to ensure the correct structure is measured. You can also add notes in the optional information section to provide additional information relevant to locating your structure.

My email said the images were unavailable. What does this mean?

Properties are measured from aerial images. In some cases these images may not be suitable for an accurate building measurement because the image quality is not sufficient (e.g. low resolution, blurry), or because too much of the building is obstructed (e.g. trees, debris). EagleView maintains a high standard for quality and accuracy and our image libraries are constantly growing. If your property cannot be accurately measured, you will not be charged for the report.

Create a custom cover page by logging in to My EagleView and choosing Account Settings. Alternatively, you can set up a custom cover page at the time your order is placed during the Add Instructions step of the ordering process. If you have questions or would like help setting up your cover page, please call customer service at 1-866-659-8439. If you already have a custom cover page associated with your EagleView account, it will be used for all QuickSquares Reports ordered.

Does the QuickSquares Report include any kind of guarantee?

We do not offer an accuracy guarantee, but as with any EagleView product, if you are not 100% satisfied your purchase price will be refunded.

What is Extended Coverage for QuickSquares?

Extended Coverage meets the demand for extended geographical coverage and the need to measure as many roofs as possible. Extended Coverage is offered as a substitution option when EagleView QuickSquares Reports are not available due to obstruction or lower-image quality. Refer to the Extended Coverage FAQ for more details.

I upgraded to a PremiumReport and the measurements are different than my QuickSquares. Why?

The QuickSquares Report provides the total rounded squares of a structure to allow you to quickly deliver an estimate. When you upgrade to a PremiumReport, the property is re-measured using EagleView's patented 3D technology to provide precise numbers for material ordering and production planning. In some cases the numbers on the reports may vary. For instance, the QuickSquares Report relies on the predominant pitch of the roof but exact pitch of each section is used for a Premium so this could result in numbers that are slightly different.

Reports

What information is included with a PremiumReport?

PremiumReports come with aerial images of the property, a 3D diagram of the roof, length, area, pitch, and note diagrams and a summary page with waste table calculations

What information is included with a StandardReport?

StandardReports come with an aerial image of the property. After [redacted] is provided through the StandardReport website a report is generated offering length, area, pitch, and note diagrams. The StandardReport is generated after the customer manually enters in the pitch values for the roof.

Can I convert a StandardReport to a PremiumReport?

This may be possible. Please call our customer service department at 1-866-659-8439 to see if we can assist you.

How do I edit and generate a StandardReport?



Action - Select the action to be performed on the roof. The options are to Repair or Replace. You may also choose No Damage to indicate damage is not present.

Roof Type - Choose the roofing materials required to complete the project (Composite, Metal, etc.)

+1 Stories – Place a checkmark in this box if additional charges are to be added based on the number of stories in the structure.

Steep Charge – Select pitch value if additional charges are to be added based on the structure's pitch.

Demolition – Choose the Demolition to be completed.

Notes – Add any notes for this area by clicking on the green plus sign in the line item. If notes are present for a line item, a blue checkmark ✓ will appear. You may also add notes by clicking on the 'Additional Notes' button.

Pic – Indicate whether pictures have been obtained for this area.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	581	("2273876" | "20020041328" | "20020041717" | "20020114536" | "20030014224" | "20030043824" | "20030088362" | "20030214585" | "20040105090" | "20040167709" | "20050073241" | "20050169521" | "20060028550" | "20060036513" | "20060092043" | "20060238383" | "20060250515" | "20070024612" | "20070046448" | "20070237420" | "20080120031" | "20080123994" | "20090177458" | "20090208095" | "20090259568" | "20090304227" | "20100296693" | "20110033110" | "3153784" | "3594556" | "3614410" | "3621326" | "3661061" | "3716659" | "3725563" | "3864513" | "3866602" | "3877799" | "4015080" | "4044879" | "4184711" | "4240108" | "4281354" | "4344683" | "4360876" | "4382678" | "4387056" | "4396942" | "4463380" | "4489322" | "4490742" | "4491399" | "4495500" | "4527055" | "4543603" | "4586138" | "4635136" | "4653136" | "4673988" | "4686474" | "4688092" | "4689748" | "4707698" | "4758850" | "4805033" | "4807024" | "4814711" | "4814896" | "4843463" | "4899296" | "4906198" | "4953227" | "4956872" | "5034812" | "5086314" | "5121222" | "5138444" | "5155597" | "5164825" | "5166789" | "5191174" | "5200793" | "5210586" | "5231435" | "5247356" | "5251037" | "5265173" | "5267042" | "5270756" | "5296884" | "5335072" | "5342999" | "5345086" | "5353055" | "5369443" | "5402170" | "5414462" | "5467271" | "5481479" | "5486948" | "5506644" | "5508736" | "5555018" | "5604534" | "5617224" | "5633946" | "5668593" | "5677515" | "5798786" | "5835133" | "5841574" | "5844602" | "5852753" | "5894323" | "5899945" | "5963664" | "6037945" | "6088055" | "6094215" | "6097854" | "6108032" | "6130705" | "6157747" | "6167300" | "6222583" | "6236886" | "6256057" | "6373522" | "6421610" | "6434280" | "6597818" | "6639596" | "6711475" | "6731329" | "6747686" | "6810383" | "6816819" | "6826539" | "6829584" | "6834128" | "6876763" | "7009638" | "7018050" | "7046401" | "7061650" |	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:45

Roofr Exhibit 1002, Page 815

		"7065260" | "7123382" | "7127346" | "7133551" | "7142984" | "7184072" | "7233691" | "7262790" | "7348895" | "7424133" | "7509241" | "7728833" | "7832267" | "7844499" | "8078396" | "8705843").PN.				
L2	151	((predominant primary average estimat$3) near pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:46
L3	0	1 and 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:46
S6	1	13/424054	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:17
S7	10	"20100179787" "20100110074" "20100114537" "20110187713" "8078436".pn. 12/090692	US-PGPUB; USPAT	OR	ON	2014/04/10 17:33
S9	21	aerial adj roof adj estimat$4	US-PGPUB; USPAT	OR	ON	2014/04/10 17:35
S10	4	(US-20100114537-$ or US-20100179787-$ or US-20100110074-$).did. or (US-8078436-$).did.	US-PGPUB; USPAT	OR	ON	2014/04/10 17:37
S11	23	predominant adj pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S12	0	S10 and S11	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S13	3	(predominant adj pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:38
S14	4	S10 and pitch	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2014/04/10 17:39

			EPO; JPO; DERWENT; IBM_TDB			
S15	8079	pitch near4 averag$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S16	0	S10 and S15	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S17	1	S15 and S7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S18	2	"20100114537" and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 21:51
S19	5	"8078436".pn. "8145840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S20	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S21	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515198".pn. "8401222".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:47
S22	2	"20100296693"	US-PGPUB; USPAT	OR	ON	2014/04/11 16:48
S23	2	"20100296693" and pitch	US-PGPUB; USPAT	OR	ON	2014/04/11 16:49
S24	1	"20130246204" and (pitch same averag$3)	US-PGPUB; USPAT	OR	ON	2014/04/11 16:58
S25	0	"20100296693" and footprint	US-PGPUB; USPAT	OR	ON	2014/04/11 21:30
S26	2	"20100296693" and computer	US-PGPUB; USPAT	OR	ON	2014/04/11 21:45
S27	2	"20100296693" and edge	US-PGPUB; USPAT	OR	ON	2014/04/11 21:53
S28	2	"20100296693" and oblique	US-PGPUB; USPAT	OR	ON	2014/04/11 21:54
S29	2	"20100296693" and orientation	US-PGPUB; USPAT	OR	ON	2014/04/11 21:55
S30	2	"20100296693" and automatic	US-PGPUB; USPAT;	OR	ON	2014/04/11 21:57

Roofr Exhibit 1002, Page 817

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S31	2	"20100296693" and automatic$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 21:57
S32	2	"20100296693" and (seller contrator retailer merchant vendor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:01
S33	22521	705/26.1-27.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S34	11	(thornberry near2 chris).in. (thornberry near2 dale).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S35	45261	(image and roof)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S36	10	S34 and S35	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S37	2	"20060200311"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:08
S38	372	(find$3 locat$3 determin$3) with (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10

Roofr Exhibit 1002, Page 818

S39	171240	"705".clas.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
S40	108	S38 and S39	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
S41	38	(find$3 locat$3 determin$3) adj2 (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S42	7	(find$3 locat$3 determin$3) adj2 (contractor adj2 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S43	31	(find$3 locat$3 determin$3) adj2 (contractor adj5 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S44	17	S39 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S45	1	"20020087332" and location	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:14
S46	17755	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:24
S47	596	(estimat$3 same roof$3 same (size area footprint))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2014/04/11 22:24

Roofr Exhibit 1002, Page 819

			DERWENT; IBM_TDB			
S48	5	S46 and S47	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S49	99	(estimat$3 same roof$3 same (size area footprint)) and aerial	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S50	1	S46 and S49	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S59	17	"8078436".pn. "8145578".pn. "8170840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:51
S60	0	(predominant adj pitch) and S59	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:54
S61	664	((predominant primary) adj2 pitch) near2 pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:57
S62	10	((predominant primary) adj2 pitch) near2 roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:57
S63	8	S59 and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:58
S64	2	13/424054 and pitch	US-PGPUB; USPAT; USOCR;	OR	ON	2014/11/20 18:04

Roofr Exhibit 1002, Page 820

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S65	0	roof same (pitch same (area near2 (percent percentage))same (sum add adding! added!) same weight$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:17
S66	34	roof same pitch same area same (weight$3 (percent percentage)) same (sum add adding! added!)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:17
S67	5	roof same area same (weight$3 near4 pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:20
S68	13	roof same (estimat$3 near2 area) same pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:21
S69	17	12/467,244	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:23
S70	6	"20060036513"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:30
S71	14	roof same (average adj pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:39
S72	70	pitch and (slope adj factor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:47
S73	8	roof and pitch and (slope adj factor)	US-PGPUB;	OR	ON	2014/11/20

Roofr Exhibit 1002, Page 821

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			18:47
S74	1	"20130246204" and "slope factor"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:52
S76	2	geoestimator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:24
S77	2	S76 and (pitch area)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:25
S78	0	eagleview and predominant	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:42
S79	0	eagleview and primary adj pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:42
S80	11	eagleview and ((determin$3 calculat$3 estimat$3) near2 pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:43
S81	3	eagleview and ((determin$3 calculat$3 estimat$3) near2 pitch).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:46
S82	14817	703/1-2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2014/11/20 20:47

Roofr Exhibit 1002, Page 822

			IBM_DB			

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S51	6384	705/26.1-27.2.ccls.	USPAT; UPAD	OR	ON	2014/04/11 22:06
S52	3	(thornberry near2 chris).in. (thornberry near2 dale).in.	USPAT; UPAD	OR	ON	2014/04/11 22:07
S53	13851	(image and roof)	USPAT; UPAD	OR	ON	2014/04/11 22:07
S54	3	S52 and S53	USPAT; UPAD	OR	ON	2014/04/11 22:07
S55	0	"20060200311"	USPAT; UPAD	OR	ON	2014/04/11 22:08
S56	3932	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	USPAT; UPAD	OR	ON	2014/04/11 22:24
S57	172	(estimat$3 same roof$3 same (size area footprint))	USPAT; UPAD	OR	ON	2014/04/11 22:25
S58	1	S56 and S57	USPAT; UPAD	OR	ON	2014/04/11 22:25
S75	5	roof same (average adj pitch)	USPAT; UPAD	OR	ON	2014/11/20 18:40
S83	5358	703/1-2.ccls.	USPAT; UPAD	OR	ON	2014/11/20 20:47

11/ 20/ 2014 9:49:16 PM
C:\ Users\ mzimmerman1\ Documents\ EAST\ Workspaces\ 13424054.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	Art Unit
	MATTHEW ZIMMERMAN	3684

CPC- SEARCHED		
Symbol	Date	Examiner
G06Q30/0621	4/11/2014	MZ
G06Q30/0641	4/11/2014	MZ

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
705	26.1,26.5,27.1	4/11/2014	MZ

SEARCH NOTES		
Search Notes	Date	Examiner

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
705	26.1,27.1,26.5	4/11/2014	MZ

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OKLAHOMA CITY, OK 73113

Courtesy Reminder for
Application Serial No: 13/424,054

Attorney Docket No: 6338.157
Customer Number: 30589
Date of Electronic Notification: 11/28/2014

This is a courtesy reminder that new correspondence is available for this application. If you have not done so already, please review the correspondence. The official date of notification of the outgoing correspondence will be indicated on the form PTOL-90 accompanying the correspondence.

An email notification regarding the correspondence was sent to the following email address(es) associated with your customer number:
dsorocco@dunlapcodding.com

To view your correspondence online or update your email addresses, please visit us anytime at **https://sportal.uspto.gov/secure/myportal/privatepair.** If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov or call 1-866-217-9197.

PTO/SB/30 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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Request for Continued Examination (RCE) Transmittal

Address to:
Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew Zimmerman
Attorney Docket Number	6338.157

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. Submission required under 37 CFR 1.114 Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

   a. ☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

      i. ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____

      ii. ☐ Other _____

   b. ☑ Enclosed

      i. ☑ Amendment/Reply

      ii. ☐ Affidavit(s)/ Declaration(s)

      iii. ☐ Information Disclosure Statement (IDS)

      iv. ☑ Other Extension of Time

2. Miscellaneous

   a. ☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of _____ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

   b. ☐ Other _____

3. Fees The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.

   a. ☐ The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any overpayments, to Deposit Account No. _____.

      i. ☑ RCE fee required under 37 CFR 1.17(e)

      ii. ☑ Extension of time fee (37 CFR 1.136 and 1.17)

      iii. ☐ Other _____

   b. ☐ Check in the amount of $ _____ enclosed

   c. ☑ Payment by credit card (Form PTO-2038 enclosed)

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

Signature	Marc Brockhaus	Date	05/27/2015
Name (Print/Type)	Marc A. Brockhaus	Registration No.	40,923

CERTIFICATE OF MAILING OR TRANSMISSION

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Mail Stop RCE, Commissioner for Patents, P. O. Box 1450, Alexandria, VA 22313-1450 or facsimile transmitted to the U.S. Patent and Trademark Office on the date shown below.

Signature	Marc Brockhaus		
Name (Print/Type)	Marc A. Brockhaus	Date	05/27/2015

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop RCE, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Electronically Transmitted: 05/27/2015 PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No:	13/424,054	Conf. No. 7006
Inventors:	Chris T. Thornberry, Dale R. Thornberry	
Filed:	Mar. 19, 2012	
TC/A.U.:	3684	
Examiner:	ZIMMERMAN, MATTHEW E.	
Title:	Method and System for Quick Square Roof Reporting	
Docket No.:	6338.157	
Customer No.:	30589	

Mail Box Non-Fee Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE

The following is being submitted in response to the Office Action dated November 28, 2014:

Amendments to the Claims begin on page **2** of this paper.

Remarks/Arguments begin on page **8** of this paper.

Amendments to the Claims

This listing of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims:

1. (Currently Amended) One or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems that when executed cause the one or more computer systems to identify a geographic location of a roof; ~~determine contact information of one or more contractors within a region of interest of the geographic location of the roof;~~ determine a footprint and predominant pitch of the roof by analyzing one or more image showing the roof; ~~determine predominant pitch of the roof; and~~ determine an estimated roofing area of the roof based on the predominant pitch and the footprint of the roof; and generate a roof report including at least one image showing the roof and the estimated roofing area of the roof.

2. (Currently Amended) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to determine contact information of one or more contractors within a region of interest of the geographic location of the roof, and to provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing

area and the contact information of one or more contractor within the region of interest of the geographic location of the roof.

3. (Previously Presented) The one or more non-transitory computer readable medium of claim 2, wherein the roof report includes contact information of the customer.

4. (Previously Presented) The one or more non-transitory computer readable medium of claim 1, wherein the one or more non-transitory computer readable medium comprises a first non-transitory computer readable medium of a first host system and a second non-transitory computer readable medium of a second host system.

5. (Previously Presented) The one or more non-transitory computer readable medium of claim 1, wherein identifying the geographic location of the roof further comprises obtaining contact information of a customer.

6. (Previously Presented) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to receive customer input to validate geographic location of the roof.

7. (Previously Presented) The one or more non-transitory computer readable medium of claim 6, wherein the geographic location includes coordinates and validation of the geographic location includes instructions for receiving customer input to alter one or more coordinates of the geographic location.

8. (Previously Presented) The one or more non-transitory computer readable medium of claim 1, wherein identifying a geographic location of the roof includes identifying one or more edges of the roof in an image.

9. (Previously Presented) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to identify edges of the roof; determine three-dimensional information of the edges including position, orientation and length using multiple oblique images from multiple cardinal directions; and, determine, automatically, one or more line segments forming a portion of a footprint of the roof utilizing position and orientation of the edges.

10. (Currently Amended) The one or more non-transitory computer readable medium of claim 1, wherein determining the predominant pitch includes determining a plurality of pitch values with each pitch value associated with a portion of the roof, the predominant pitch based on the plurality of pitch values.

11. (Previously Presented) The one or more non-transitory computer readable medium of claim 10, wherein each pitch value is associated with an estimated percentage of roof area to provide an average pitch value.

12. (Previously Presented) The one or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems of claim 1, that when executed further cause the one or more computer systems to provide the roof report to one or more contractors, the contractor located within the region of interest of the geographic location of the roof.

13. (Currently Amended) A system, comprising:

two or more host systems, each host system having one or more non-transitory computer readable medium;

the non-transitory computer readable medium of the first host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

identify a geographic location of a roof;

determine contact information of at least one contractor within a region of interest about the geographic location of the roof;

the non-transitory computer readable medium of the second host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

determine a footprint and predominant pitch of the roof by analyzing one or more image showing the roof;

~~determine a predominant pitch;~~

determine an estimated roofing area based on the predominant pitch and the footprint of the roof; and,

provide a roof report, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractors within the region of interest.

14. (Currently Amended) A roofing estimate method, comprising:

receiving, by at least one computer processor from a user via a user terminal, a geographic location of a roof;

providing to the user, with the computer processor, imagery of the roof based on the geographic location of the roof;

determining and providing, with the computer processor, an estimated roofing area based at least on a predominant pitch and a footprint of the roof by analyzing one or more image showing the roof, the footprint of the roof determined at least in part using at least one image of the roof; and

providing, with the computer processor, contact information of one or more roofing contractors within a region of interest of the geographic location of the roof.

15. (Currently Amended) The roofing estimate method of claim 14, further comprising:

providing, with the computer processor, a roof report, wherein the roof report includes one or more ortho images of the roof, ~~one or more oblique images of the roof,~~ the estimated roofing area and the contact information of one or more contractor within the region of interest of the geographic location of the roof.

16. (Previously Presented) The roofing estimate method of claim 14, wherein the footprint of the roof is determined at least in part with oblique images of the roof.

17. (Previously Presented) The roofing estimate method of claim 14, wherein the predominant pitch value of the roof based at least in part on the footprint of the roof as a boundary of the roof.

18. (Previously Presented) The roofing estimate method of claim 14, wherein the predominant pitch is based on a weighted average of individual pitch factors for two or more portions of the roof.

REMARKS

This is intended to be a complete response to the Office Action mailed November 28, 2014, in which claims 1- 18 were rejected. Claims 1-18 are pending, with claims 1, 13, and 14 being independent. Claims 1, 2, 10, 13, 14, and 15 have been amended. No new subject matter has been added.

Based on the preceding amendments and the following remarks, Applicants respectfully request the withdrawal of the rejections and the issuance of a timely notice of allowance for claims 1-18.

Claim Amendments

Applicants respectfully submit that the amendments to claims 1, 13, and 14 do not introduce any new matter. Written description and enablement support for the claims can be found, for example, in original claim 1 and paragraphs [0073] - [0076] of the above-referenced patent application as originally filed. Therefore, no new matter is added by the amendments.

Claim Rejection – 35 U.S.C. § 101

Claims 1-18 were rejected under 35 U.S.C. § 101 as being directed to non-statutory subject matter. The Office Action stated that the claims as a whole, considering all claim elements both individually and in combination, do not amount to significantly more than an abstract idea. The Office Action asserted that the claims are directed "to the abstract idea of estimating areas."

Further, the Office Action stated that the additional elements in the claims other than the abstract idea amount to no more than: (i) mere instructions to implement the idea on a computer, and/or (ii) recitation of generic computer structure that serves to perform generic computer functions that are well-understood, routine, and conventional activities previously known to the pertinent industry. The Office Action further stated that, viewed as a whole, the additional claim elements do not provide meaningful limitations to transform the abstract idea into a patent eligible application of the abstract idea such that the claims amount to significantly more than the abstract idea itself.

Applicant respectfully asserts that claims 1-18 provide novel and non-obvious functions specific to the field of computer technologies and are patent eligible under 35 U.S.C. §101. Although the Applicant respectfully disagrees with the rejections of claims 1-18, such claims have been amended to expedite the prosecution and more clearly conform with the eligibility requirements under 35 U.S.C. § 101 in light of the Supreme Court's *Alice Corp.* opinion. Since this Office Action was mailed in November 2014, the USPTO has issued Interim Guidance on Patent Subject Matter Eligibility (hereinafter "Interim Guidance") "which supplements the June 25, 2014, Preliminary Examination Instructions in view of the Supreme Court decision in *Alice Corp.* (June 2014 Preliminary Instructions) and supersedes the March 4, 2014, Procedure for Subject Matter Eligibility Analysis of Claims Reciting Or Involving Laws of Nature/Natural Principles, Natural Phenomena, And/Or Natural Products (March 2014 Procedure) issued in view of the Supreme Court decisions in *Myriad* and *Mayo*."

See Federal Register Vol. 79, No. 241 at 74619. The USPTO is also seeking public comment on the Interim Guidance and has set a deadline of March 16, 2015 for receiving comments[1]. Interestingly enough, a variety of intellectual property organizations and companies have submitted comments including the AIPLA, the American Bar Association, IBM, Microsoft and Google trying to interpret the Interim Guidance and pointing out where the Interim Guidance can be improved to assist the Examiners and Applicants in applying the law with respect to eligibility in a consistent manner. As will be discussed in detail below, Applicant respectfully submits that claims 1-18 are patent-eligible under both the guidance issued by the Supreme Court in *Alice Corp. Pty. Ltd. v. CLS Bank Int'l*, 134 S. Ct. 2347 (2014) and the Interim Guidance issued December 16, 2014 by the United States Patent and Trademark Office (hereinafter referred to as "the Office").

Claims 1-20 are Patent Eligible under 35 U.S.C.§101

35 U.S.C. § 101 provides that "whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title." As noted by the Office in its Interim Guidance, the Supreme Court has long held that §101 excludes certain subject matter from patent eligibility including abstract ideas, laws of Nature/Natural

[1] The comments are available on the USPTO's website at http://www.uspto.gov/patent/laws-and-regulations/comments-public/comments-2014-interim-guidance-patent-subject-matter.html.

Principles and Natural Phenomena. These are referred to in the Interim Guidance as "Judicial Exceptions."

In *Alice*, the Supreme Court noted that an abstract idea itself is not eligible for patent protection since it is considered a principle, an original cause, a motive. *Alice*, 573 U.S. at 2355 (citing *Gottschalk v. Benson*, 409 US. 63, 67 (1972) and *Le Roy v. Tatham*, 55 U.S. 156 (1852)). However, as the Supreme Court recognized, every invention can be characterized at some level as an abstract idea. *Id.* at 2354. As described in *Alice*, step 1 of the *Mayo* test is not asking the Examiner to simply identify an abstract idea, rather it asks the Examiner to "determine whether the claims at issue are *directed to* one of those patent-ineligible concepts." *Id.* at 2355 (emphasis added). If the question were simply asking "What is the abstract idea?", every single patent claim would satisfy *Mayo* step 1 as being directed to an abstract idea – which is why the Supreme Court stated "[a]n invention is not rendered ineligible for patent simply because it involves an abstract concept. Applications of such concepts 'to a new and useful end,' remain eligible for patent protection." and cautioned that "we tread carefully in construing this exclusionary principle lest it swallow all of patent law." *Id.* at 2354.

Likewise, the Federal Circuit has stated that it would "not presume to define 'abstract' beyond the recognition that this disqualifying characteristic should exhibit itself so manifestly as to override the broad statutory categories of eligible subject matter and the statutory context that directs primary attention on the patentability criteria of the rest of the Patent Act." (*Research Corp. Techs. v.*

Microsoft Corp., 627 F.3d 859, 868; 97 U.S.P.Q.2D (BNA) 1274, Fed. Cir. 2010, finding the patent claims at issue not to be invalid under §101 since the invention claimed "presents functional and palpable applications" in its field.)

This is also why the Interim Guidance states "[c]ourts tread carefully in scrutinizing such claims because at some level all inventions embody, use, reflect, rest upon or apply a law of nature, natural phenomenon, or abstract idea." Interim Guidance at 74622, first column. The Interim Guidance mandates that the Examiner "determine whether the claim as a whole is directed to a judicial exception." See Interim Guidance at 74622, first column. The Interim Guidance clearly acknowledges that claims directed to a particular application of a judicial exception are patent - eligible, i.e., "[a]s an example, a robotic arm assembly having a control system that operates using certain mathematical relationships is clearly not an attempt to tie up use of the mathematical relationships and would not require a full analysis to determine eligibility." See Interim Guidance at 74625.

Additionally, the Federal Circuit has stated that the,

> "Supreme Court has already made abundantly clear that inventions incorporating and relying upon even 'a well known mathematical equation' do not lose eligibility because 'several steps of the process [use that] mathematical equation.' *Diehr, 450 U.S. at 185.* Indeed, the Supreme Court counseled: 'In determining the eligibility of respondents' claimed process for patent protection under section 101, their claims must be considered as a whole. It is inappropriate to dissect the claims into old and new elements and then to ignore the presence of the old elements in the analysis. This is particularly true in a process claim because a new combination of steps may be patentable even though all the constituents of the combination were well known and in common use before the combination was made.'

Research Corp. Techs. v. Microsoft Corp., 627 F.3d 859, 868; 97 U.S.P.Q.2D (BNA) 1274, Fed. Cir. 2010, citing *Diamond v. Diehr*, 450 U.S. 175, 188, 101 S. Ct. 1048, 1058, 209 U.S.P.Q. (BNA) 1 (U.S. 1981).

In analyzing the rejection, the Interim Guidance directs the Examiner to "identify the exception by referring to where it is recited (i.e., set forth or described) in the claim and explain why it is considered an exception. [Emphasis Added] See Interim Guidance at 74624, third column. Then, if the claim includes additional elements, identify the elements in the rejection and explain why they do not add significantly more to the exception." [Emphasis Added.] See Interim Guidance at 74624, third column. In other words, the Interim Guidance is directing Examiners to analyze all of the limitations in the claims and to provide a *prima facie* case of ineligibility for any §101 rejections.

In the present application, Applicant respectfully submits that a *prima facie* case of ineligibility has not been presented for Claims 1-18. In formulating the rejection, the Office Action contends that "[t]he claims is/are directed to the abstract idea of estimating area." But, "estimating area" is not claim language used in claims 1-18, and the Office Action does not explain why "estimating area" is a judicial exception. The Office Action also does not specifically identify any additional elements in claims 1-18, or explain why the language in all 18 claims does not add significantly more to the exception. In fact, the Office Action addresses all of the pending claims by stating that such are "no more than: (i) mere instructions to implement the idea on a computer, and/or (ii) recitation of generic computer structure that serves to perform generic computer functions

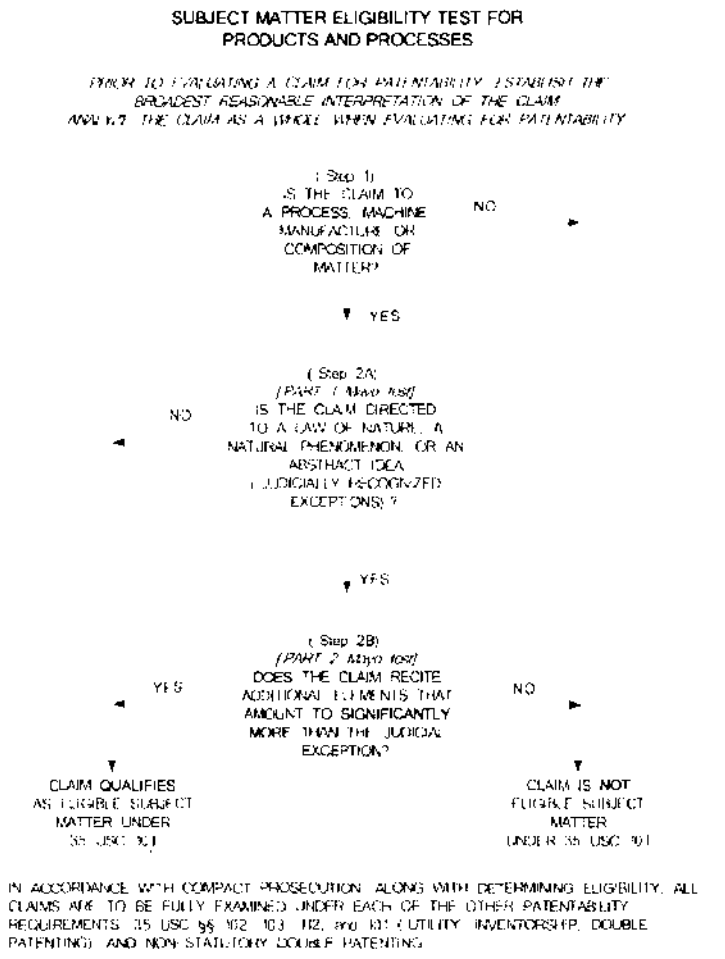
that are well-understood, routine, and conventional activities previously known to the pertinent industry" (see pages 2-3 of the Office Action) without providing any evidentiary support for these findings[2]. Under the Administrative Procedures Act and controlling federal case law, examiners must provide "substantial evidence" in support of all rejections. *In re Lee*, 61 USPQ 2d 1430 (Fed. Cir. 2002); *Dickinson v. Zurko*, 527 U.S. 150 (1999). Conjecture, conclusory statements, or personal opinions cannot meet this requirement. *See* Administrative Procedure Act, 5 U.S.C. 500 *et seq.*; *In re Gartside*, 203 F.3d 1305, 1315 (Fed. Cir. 2000); *In re Dembiczak*, 175 F.3d 994, 999-1000 (Fed. Cir. 1999) (broad conclusory statements about the teaching of references are not "substantial evidence").

Even though a *prima facie* case of ineligibility has not been made, claims 1-18, as amended, will be compared to the Office's Interim Guidance to demonstrate why such claims are patent-eligible.

The Office's Interim Guidance sets forth a chart summarizing its Subject Matter Eligibility Test for Products and Processes. The Office's chart is set forth below for the Examiner's convenience.

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[2] This statement is not understood because the "Examiner agrees that the prior art of record fails to teach 'predominant pitch'" which is recited in all 18 claims. See Page 4, Paragraph 9 of the Office Action.



Step 1 of the chart asks whether the claim is directed to a process, machine, manufacture or composition of matter. In this case, claims 1-12 set forth "one or more non-transitory medium" which qualifies as a "manufacture," claim 13 sets forth a "system" which qualifies as a machine, and claims 14-18 sets forth a "roofing estimate method" which qualifies as a process. Thus, claims 1-18 are all patent eligible under the first box of the subject matter eligibility test.

The next step, i.e. Step 2A, asks whether the claim is "directed to" a law of nature, a natural phenomenon, or an abstract idea. In interpreting Step 2A, the Office has provided the following guidelines:

> A claim is directed to a judicial exception when a law of nature, a natural phenomenon, or an abstract idea is recited (i.e., set forth or described) in the claim. Such a claim requires closer scrutiny for eligibility because of the risk that it will "tie up" the excepted subject matter and pre-empt others from using the law of nature, natural phenomenon, or abstract idea. Courts tread carefully in scrutinizing such claims because at some level all inventions embody, use, reflect, rest upon, or apply a law of nature, natural phenomenon, or abstract idea. To properly interpret the claim, it is important to understand what the applicant has invented and is seeking to patent. For claims that may recite a judicial exception, but are directed to inventions that clearly do not seek to tie up the judicial exception, see Section I.B.3. regarding a streamlined eligibility analysis. [Emphasis Added] See Interim Guidance at 74622, First Column.

In this case, claims 1-12 specifies "determining an estimated roofing area." Even assuming that "determining an estimated roofing area" falls within one of the judicial exceptions, it is believed that claim 1 clearly does not seek to tie up the judicial exception and is therefore patent eligible under the "streamlined eligibility analysis." In particular, claims 1-12, as amended, specifically "determine[s] a footprint and predominant pitch of the roof by analyzing one or more image showing the roof" and the "estimated roofing area" being "based on the predominant pitch and the footprint of the roof." These are meaningful limitations that do not pre-empt all forms of "estimating area" or even "determining an estimated roof area." As in the Supreme Court *Diehr*[3] case, Applicant does not "seek to patent a mathematical formula" and does not "seek to pre-empt the use

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[3] *Diamond v. Diehr*, 450 U.S. 175, 187, 101 S. Ct. 1048, 1057, 209 U.S.P.Q. (BNA) 1 (U.S. 1981).

of that equation." From the language of claim 1, it is apparent that the claimed invention is not directed to all forms of estimating area, but rather is tailored to a specific patent eligible application involving the determination of "an estimated roofing area" using a specified methodology, i.e., "based on the predominant pitch and the footprint of the roof" determined by "analyzing one or more image showing the roof."

Claims 1-12 do not preempt and disproportionately tie up the use of any abstract idea. To assist the Examiner in addressing the Applicant's response, the Examiner's attention is directed to the comments to the Interim Guidance provided by the AIPLA, which point out:

> The Guidance does not address how applicants may respond to such rejections nor how examiners are to evaluate such rebuttal arguments. Applicants should be able to rebut a rejection by submitting prior art that describes another use of the abstract idea or law of nature evidencing that the claimed invention does not risk "disproportionately tying up" the use of the underlying ideas. [footnote citing to *Alice*, 134 S. Ct. at 2354-2355, quoting *Mayo*, 132 S. Ct. at 1294]. Examiners should be instructed that if the applicant does so, the 101 rejection should be withdrawn. See page 13 of 14.

In this case, the Examiner's attention is respectfully directed to the Thornberry reference, i.e., U.S. Patent Publication No. 20100296693, of record, which shows and discusses measuring the area of a roof in Figures 5E-5F, and Paragraphs [0002], and [0103] – [0112]. For example, Paragraph [0002] states:

> [0002] Roof measuring, for example, dimension, length and areas has been done for many years, such as in connection with for estimating and bidding roofing jobs. Also, for many years, companies and products have offered such estimation services and reporting software reports using aerial imagery on which roof line outlines are traced, dimensions and areas are automatically based on those tracings, and vertical elevations (via pitch or otherwise) are included in mathematical models.

When one reviews the language of claims 1-12 as a whole as instructed by the Interim Guidance and the prior art to determine whether the claimed invention preempts and disproportionately ties up the use of the underlying ideas, it is apparent that claims 1-12 do not seek to tie up any judicial exception such that others cannot practice it. Claims 13-18 contain similar limitations and are eligible for the same reasons as claims 1-12. Under the Office's Interim Guidance, claims 1-18 do not need to proceed through a full analysis as their eligibility is self-evident. Therefore, Applicant respectfully requests withdrawal of the rejection of claims 1-18.

The Claimed Invention Amounts to Significantly more than a Judicial Exception

As discussed above, Applicant respectfully submits that claims 1-18 provide novel and non-obvious functions specific to the field of computer technologies, do not seek to tie up any judicial exception and are thus eligible for streamlined analysis. However, assuming for the sake of argument, that claims 1-18 were considered to be directed to a judicial exception, Applicant respectfully submits that claims 1-18 include significantly more than the judicial exception and are therefore patent eligible.

As outlined in the Interim Guidance, if a claim is directed to a judicial exception, the Examiner should proceed to Step 2B of the analysis. Step 2B asks whether any element, or combination of elements, in the claim is sufficient to ensure that the claim amounts to significantly more than the judicial exception.

To assist Examiners in interpreting step 2B, the Office has provided the following guidance:

> A claim directed to a judicial exception must be analyzed to determine whether the elements of the claim, considered both individually and as an ordered combination, are sufficient to ensure that the claim as a whole amounts to significantly more than the exception itself – this has been termed a search for an "inventive concept." To be patent-eligible, a claim that is directed to a judicial exception must include additional features to ensure that the claim describes a process or product that applies the exception in a meaningful way, such that it is more than a drafting effort designed to monopolize the exception. It is important to consider the claim as whole. Individual elements viewed on their own may not appear to add significantly more to the claim, but when combined may amount to significantly more than the exception. Every claim must be examined individually, based on the particular elements recited therein, and should not be judged to automatically stand or fall with similar claims in an application. [Emphasis Added] Interim Guidance at 74624.

The Office provided further guidance as to what may be enough to qualify as "significantly more" using limitations identified by the Supreme Court which includes:

> Improvements to another technology or technical field;
>
> Adding a specific limitation other than what is well-understood, routine and conventional in the field, or adding unconventional steps that confine the claim to a particular useful application. See Interim Guidance at 74624, middle column.

Applicant respectfully submits that claims 1-18 all recite the determination of an estimated roofing area based on the predominant pitch and the footprint of the roof. Thus, claims 1-18 include improvements to technology for a particular application, i.e., determining an estimated roofing area, and not simply to "estimating area." Further, as acknowledged in the Office Action, "[t]he Examiner agrees that the prior art of record fails to teach "predominant pitch" as explained

in paragraphs [0076] to [0078] and Fig. 7 of the applicant's specification." See Page 4, Paragraph 9 of the Office Action. The "determination of an estimated roofing area based on the predominant pitch and the footprint of the roof" provides an unconventional step that confines claims 1-18 to a particular useful application and renders claims 1-18 patent eligible under the Office's Interim Guidance.

Additionally, the Interim Guidance states that limitations that may be enough to qualify as "significantly more" when recited in a claim with a judicial exception include effecting a transformation or reduction of a particular article to a different state or thing. Interim Guidance at 74624. Transformation may be demonstrated through transformation of data. For example, in *PNC Bank v. Secure Axcess,* (CBM2014-00100, Decision - Institution of Covered Business Method Patent Review, Entered Sep. 9, 2014, Paper 10 at p.24), the PTAB panel found the claim at issue met the transformation prong of the machine-or-transformation test because "[t]he claim language requires '*transforming*' one thing ('received data') 'to create' something else ('formatted data') and further recites a particular manner of transforming ('by inserting an authenticity key')." Likewise, the "determination of an estimated roofing area based on the predominant pitch and the footprint of the roof" provides a transformation that qualifies claims 1-18 as significantly more than a judicial exception.

Therefore, Applicant respectfully submits that claims 1-18 are patent-eligible under 35 U.S.C. § 101.

Claim Rejection – 35 U.S.C. § 102(b)

Claims 14-18 were rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Thornberry (US 2010/0296693). In formulating the rejection, the Office Action contends that Thornberry teaches receiving [data] (see Thornberry Fig. 4A-B); and providing [data] (see Thornberry Fig. 4A-B).

The Office Action noted that the data provided and data received was "non-functional descriptive material" because it does not functionally affect the way in which the receiving and providing are performed. Although the Applicant respectfully disagrees with the present rejection of claims 14-18, claims 14-18 have been amended to specify "determining and providing, with the computer processor, an estimated roofing area based at least on a predominant pitch and a footprint of the roof." These limitations set forth a novel function specific to the field of computer technologies which is not described in the Thornberry reference. Thus, it is respectfully submitted that the present rejection under 35 U.S.C. §102 has been overcome.

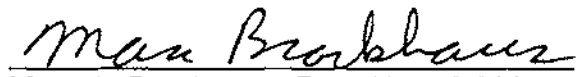
In light of the foregoing, reconsideration and withdrawal of the rejection of claims 14-18 under 35 U.S.C. § 102 is respectfully requested.

CONCLUSION

The foregoing is intended to be a complete response to the Office Action dated November 28, 2014. Applicants respectfully request reconsideration and withdrawal of the rejections set forth in the Office Action and a timely notice of allowance for all of the pending claims 1-18. Should the Examiner have any

questions or comments regarding the foregoing, or any other matter, the undersigned would welcome a telephonic interview with the Examiner.

Respectfully Submitted,



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Attorney for Applicants

Electronic Patent Application Fee Transmittal

Application Number:	13424054
Filing Date:	19-Mar-2012
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Marc Alan Brockhaus/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension - 3 months with $0 paid	2253	1	700	700
Miscellaneous:				
Request for Continued Examination	2801	1	600	600
		Total in USD ($)		**1300**

Electronic Acknowledgement Receipt

EFS ID:	22463746
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Marc Alan Brockhaus/Lori Radford
Filer Authorized By:	Marc Alan Brockhaus
Attorney Docket Number:	6338.157
Receipt Date:	27-MAY-2015
Filing Date:	19-MAR-2012
Time Stamp:	17:41:58
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$1300
RAM confirmation Number	4584
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	6338157_Transmittal05272015.pdf	67103 91d8191be2153f57d0d0dd17ea7691c6e2e5ce9bb	no	1
Warnings:					
Information:					
2	Extension of Time	6338157_Extension05272015.pdf	62798 2e829e156a03b7568866b1e65e1e51d9ec40f	no	1
Warnings:					
Information:					
3	Request for Continued Examination (RCE)	6338157_RCE.pdf	81273 67061ea715e1c166e019197d8866168189 6addde6	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
4		6338157_Response05272015.pdf	842246 e8fbe9e2d777a0de9f5fe9d1f1de4b45d9ff8db	yes	22

Multipart Description/PDF files in .zip description

Document Description	Start	End
Response After Final Action	1	1
Claims	2	7
Applicant Arguments/Remarks Made in an Amendment	8	22

Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	32232 9806778a84d8847f99e1501bdfe72e196d6e16e116	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1085652		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Doc Code: TRAN.LET

Document Description: Transmittal Letter

PTO/SB/21 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
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TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew Zimmerman
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☑ Amendment/Reply
  - ☑ After Final
  - ☐ Affidavits/declaration(s)
- ☑ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please Identify below):
  See Remarks

Remarks

ELECTRONICALLY TRANSMITTED:
1. SB21 Transmittal Form (1 pg);
2. SB22 Extension of Time (1 pg);
3. SB30 Request for Continued Exam (1 pg);
4. Response (22 pgs).

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	DUNLAP CODDING, P.C.		
Signature	Marc Brockhaus		
Printed name	Marc A. Brockhaus		
Date	05/27/2015	Reg. No.	40,923

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	Marc Brockhaus		
Typed or printed name	Marc A. Brockhaus	Date	05/27/2015

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/22 (03-13)
Approved for use through 3/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) 6338.157
Application Number 13/424,054	Filed 03/19/2012
For Chris T. Thornberry	
Art Unit 3684	Examiner Matthew Zimmerman

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

		Fee	Small Entity Fee	Micro Entity Fee	
☐	One month (37 CFR 1.17(a)(1))	$200	$100	$50	$
☐	Two months (37 CFR 1.17(a)(2))	$600	$300	$150	$
☑	Three months (37 CFR 1.17(a)(3))	$1,400	$700	$350	$ 700.00
☐	Four months (37 CFR 1.17(a)(4))	$2,200	$1,100	$550	$
☐	Five months (37 CFR 1.17(a)(5))	$3,000	$1,500	$750	$

☑ Applicant asserts small entity status. See 37 CFR 1.27.

☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.

☐ A check in the amount of the fee is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number _____.

☑ Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant.

☑ attorney or agent of record. Registration number 40,923.

☐ attorney or agent acting under 37 CFR 1.34. Registration number _____.

Marc Brockhaus — Signature

05/27/2015 — Date

Marc A. Brockhaus — Typed or printed name

405-607-8600 — Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

☐ * Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014 OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/424,054	Filing Date 03/19/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 = *		X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 = *		X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	05/27/2015	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 18	Minus	** 20	= 0	x $40 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	x $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/JUDY SWAYNE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

30589 7590 07/08/2015
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

EXAMINER	
ZIMMERMAN, MATTHEW E	
ART UNIT	PAPER NUMBER
3684	

DATE MAILED: 07/08/2015

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

TITLE OF INVENTION: Method and System for Quick Square Roof Reporting

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	10/08/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

30589 7590 07/08/2015
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

TITLE OF INVENTION: Method and System for Quick Square Roof Reporting

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	10/08/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
ZIMMERMAN, MATTHEW E	3684	705-026100

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively, 1
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ☐ Issue Fee
- ☐ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ☐ Payment by credit card. Form PTO-2038 is attached.
- ☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ☐ Applicant certifying micro entity status. See 37 CFR 1.29 — NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ☐ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ☐ Applicant changing to regular undiscounted fee status. — NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature Date

Typed or printed name Registration No.

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

30589 7590 07/08/2015

DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

EXAMINER	
ZIMMERMAN, MATTHEW E	
ART UNIT	**PAPER NUMBER**
3684	

DATE MAILED: 07/08/2015

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 13/424,054	Applicant(s) THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *05/27/2015*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-18*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☒ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☒ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/MATTHEW ZIMMERMAN/
Primary Examiner, Art Unit 3684

DETAILED ACTION

Examiner's Amendment

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The claims have been amended in accordance with an interview with the attorney of record as follows:

1. (Currently Amended) One or more non-transitory computer readable medium storing a set of computer executable instructions for running on one or more computer systems that when executed cause the one or more computer systems to: identify a geographic location of a roof; determine a footprint and predominant pitch of the roof by analyzing one or more image showing the roof; ~~and~~ determine an estimated roofing area of the roof based on the predominant pitch and the footprint of the roof; and generate a roof report for determination of an amount of materials needed for a construction project, wherein the roof report includes ~~including~~ at least one image showing the roof and the estimated roofing area of the roof.

13. (Currently Amended) A system, comprising:

two or more host systems, each host system having one or more non-transitory computer readable medium;

the non-transitory computer readable medium of the first host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

identify a geographic location of a roof;

determine contact information of at least one contractor within a region of interest about the geographic location of the roof;

the non-transitory computer readable medium of the second host system storing a set of computer executable instructions that when executed by one or more processors causes the one or more processors to:

determine a footprint and predominant pitch of the roof by analyzing one or more image showing the roof;

determine an estimated roofing area based on the predominant pitch and the footprint of the roof; and,

generate ~~provide~~ a roof report for determination of an amount of materials needed for a construction project, wherein the roof report includes one or more ortho images of the roof, one or more oblique images of the roof, the estimated roofing area and contact information of one or more contractors within the region of interest.

14. (Currently Amended) A roofing estimate method, comprising:

receiving, by at least one computer processor from a user via a user terminal, a geographic location of a roof;

providing to the user, with the computer processor, imagery of the roof based on the geographic location of the roof;

determining and providing, with the computer processor, an estimated roofing area based at least on a predominant pitch and a footprint of the roof by analyzing one or more image showing the roof, the footprint of the roof determined at least in part using at least one image of the roof; and

generating, with the computer processor, a roof report for determination of an amount of materials needed for a construction project, wherein the roof report includes at least one image showing the roof and the estimated roofing area of the roof ~~providing, with the computer processor, contact information of one or more roofing contractors within a region of interest of the geographic location of the roof~~.

15. (Currently Amended) The roofing estimate method of claim 14, ~~further comprising:~~

wherein the roof report further includes ~~providing, with the computer processor, a roof report, wherein the roof report includes one or more ortho images of the roof, the estimated roofing area and the~~ contact information of one or more contractor within a ~~the~~ region of interest of the geographic location of the roof.

Reasons for Allowance

In the present application, claims 1-18 are allowed. The following is the Examiner's statement of reasons for allowance:

The prior art of record neither alone nor in combination anticipates nor renders obvious the present invention. The allowable features of claim 1: determine an estimated roofing area of the roof based on the predominant pitch and the footprint of the roof. The allowable features of claims 13 and 14 are the same as claim 1 as they contain the similar allowable claim language.

The most related prior art patent of record is Thornberry (US 20100296693) which teaches determining pitch of a roof and the most related non-patent literature of record is Reference U (see PTO-892) which teaches determining pitch of a roof. However, Thornberry and Reference U neither teach nor render obvious: determine an estimated roofing area of the roof based on the predominant pitch and the footprint of the roof. The allowable features of claims 13 and 14 are the same as claim 1 as they contain the similar allowable claim language.

For these reasons, the Examiner asserts that the claims are allowable because the prior art does not anticipate them or render them obvious to a person of ordinary skill in the art.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to MATTHEW ZIMMERMAN whose telephone number is (571)270-5278. The examiner can normally be reached on Mon-Fri 9:00am-5:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jason B. Dunham can be reached on (571) 272-8109. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MATTHEW ZIMMERMAN/
Primary Examiner, Art Unit 3684

Examiner-Initiated Interview Summary	Application No.	Applicant(s)	
	13/424,054	THORNBERRY ET AL.	
	Examiner	Art Unit	
	MATTHEW ZIMMERMAN	3684	

All participants (applicant, applicant's representative, PTO personnel):

(1) *MATTHEW ZIMMERMAN*. (3)_____.

(2) *MARC BROCKHAUS*. (4)_____.

Date of Interview: *23 June 2015*.

Type: ☒ Telephonic ☐ Video Conference
☐ Personal [copy given to: ☐ applicant ☐ applicant's representative]

Exhibit shown or demonstration conducted: ☐ Yes ☒ No.
If Yes, brief description: _____.

Issues Discussed ☒101 ☐112 ☐102 ☐103 ☐Others
(For each of the checked box(es) above, please describe below the issue and detailed description of the discussion)

Claim(s) discussed: *ALL*.

Identification of prior art discussed: *N/A*.

Substance of Interview
(For each issue discussed, provide a detailed description and indicate if agreement was reached. Some topics may include: identification or clarification of a reference or a portion thereof, claim interpretation, proposed amendments, arguments of any applied references etc...)

The Examiner proposed an amendment to place the application in condition for allowance. After some deliberation, the attorney of record agreed to said amendment which is reflected in the notice of allowability. This concluded the interview.

Applicant recordation instructions: It is not necessary for applicant to provide a separate record of the substance of interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

☐ Attachment

/MATTHEW ZIMMERMAN/ Primary Examiner, Art Unit 3684	

Notice of References Cited	Application/Control No. 13/424,054	Applicant(s)/Patent Under Reexamination THORNBERRY ET AL.	
	Examiner MATTHEW ZIMMERMAN	Art Unit 3684	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2002/0087332 A1	07-2002	Como, Brian	705/1
*	B	US-2010/0114537 A1	05-2010	Pershing, Chris	703/1
*	C	US-2010/0110074 A1	05-2010	Pershing, Chris	345/423
*	D	US-2010/0179787 A2	07-2010	Pershing et al.	702/156
*	E	US-2010/0296693 A1	11-2010	Thornberry et al.	382/100
*	F	US-8,078,436 B2	12-2011	Pershing et al.	703/2
*	G	US-8,209,152 B2	06-2012	Pershing, Chris	703/1
*	H	US-2012/0179431 A1	07-2012	Labrie et al.	703/1
*	I	US-8,401,222 B2	03-2013	Thornberry et al.	382/100
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Jan. 2010 - http://aims.jocogov.org/Resources/Pictometry_Resources/POLQuickStart.pdf
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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CONFIRMATION NO. 7006

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/424,054	03/19/2012 RULE	705	3684	6338.157

APPLICANTS

INVENTORS

Chris T. Thornberry, Indianapolis, IN;
Dale R. Thornberry, Carmel, IN;

** **CONTINUING DATA** **********

** **FOREIGN APPLICATIONS** **********

** IF **REQUIRED, FOREIGN FILING LICENSE GRANTED** ** ** SMALL ENTITY **
03/30/2012

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and Acknowledged /MATTHEW E ZIMMERMAN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		IN	9	13	2

ADDRESS

DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113
UNITED STATES

TITLE

Method and System for Quick Square Roof Reporting

FILING FEE RECEIVED	FEES: Authority has been given in Paper	☐ All Fees
595	No._____ to charge/credit DEPOSIT ACCOUNT	☐ 1.16 Fees (Filing)
	No._____ for following:	☐ 1.17 Fees (Processing Ext. of time)
		☐ 1.18 Fees (Issue)
		☐ Other _____
		☐ Credit

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	Art Unit
	MATTHEW ZIMMERMAN	3684

CPC						
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NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	18	
/MATTHEW ZIMMERMAN/ Primary Examiner.Art Unit 3684	06/23/2015	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	7

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	Art Unit
	MATTHEW ZIMMERMAN	3684

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION												
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CROSS REFERENCE(S)														
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)													

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	18	
/MATTHEW ZIMMERMAN/ Primary Examiner.Art Unit 3684	06/23/2015	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	7

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	**Art Unit**
	MATTHEW ZIMMERMAN	3684

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
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NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	18	
/MATTHEW ZIMMERMAN/ Primary Examiner.Art Unit 3684	06/23/2015	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	7

http://scholar.google.com/s ... predominant pitch roof - G...
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Web Images More... MEZimm@gmail.com

Google predominant pitch roof

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[HTML] Extensive green **roofs** in London urbanhabitats.org [HTML]
G Grant - Urban Habitats, 2006 - urbanhabitats.org
... CUE Building at the Horniman Museum, in Forest Hill, south London, with a 250-square-meter **pitched roof**, was also ... and has an 8-degree **pitch**; the other is north facing and has a 27-degree **pitch** (Figure 2 ... Sedum **roofs** are the **predominant** type of extensive green **roof** in London ...
Cited by 58 Related articles All 7 versions Cite Save More

On the wind-loading mechanism of **roofing** elements
C Kramer, HJ Gerhardt, HW Kuster - Journal of Wind Engineering and ..., 1979 - Elsevier
... Fig. 3 is generally valid for **pitched**-roofed buildings and seems to be useful for codinz purposes. ... Fig.3 Simplified pressure distributions for **roofs** with various **pitch** angle. ... The **predominant** geometric parameter for the pressure distribution is the tile thickness t related to the non ...
Cited by 27 Related articles Cite Save

Roof selection for rainwater harvesting: quantity and quality assessments in Spain uab.es [PDF]
R Farreny, T Morales-Pinzón, A Guisasola, C Taya, ... - Water research, 2011 - Elsevier
... variables were the runoff and the physical–chemical parameters; and rainfall height, **predominant** wind orientation ... Depending on the local rainfall profile (either **predominance** of small or large rain events ... affect the runoff from M and P **roofs** (the only single **pitch** sloping **roofs**). ...
Cited by 66 Related articles All 10 versions Cite Save

Environmental adaptation and structural design in axially-**pitched** longhouses from Neolithic Europe
A Marshall - World Archaeology, 1981 - Taylor & Francis
... 1700 m, where rectangular longhouses, the most widespread Melanesian type, become the **predominant** traditional form ... from Britain and mainland Europe has a mean value of axial **pitch** (x) of ... 4) shows that, during the winter period, the winds are **predominantly** from the south ...
Cited by 11 Related articles All 3 versions Cite Save

Detection of adducts of deoxyribonucleic acid in white blood cells of roofers by ^{32}P-postlabeling: Relationship of adduct levels to measures of exposure to polycyclic ... sjweh.fi [PDF]
R Herbert, M Marcus, MS Wolff, FP Perera, ... - Scandinavian journal of ..., 1990 - JSTOR
... of an old **pitch roof** followed by the replacement of each sec- tion with a new asphalt **roof**. ... many consecutive weeks they had worked with hot **pitch** or asphalt or per- formed **pitch** tear-off ... are shown in figure 1. The majority of the samples from the roofers showed one **predominant** ...
Cited by 47 Related articles All 7 versions Cite Save

A rational approach to greenhouse design plastiques-agriculture.com [PDF]
BJ Bailey, GM Richardson - II Workshop on Greenhouse Construction ..., 1989 - actahort.org
... low cost of construction and low operating costs, which, in northern latitudes, is **predominantly** the cost ... for the 25° reference house will increase and the sensitivity of cost to **roof pitch** will also ... the light transmission of a curved **roof** greenhouse was equal to a **pitched roof** house in ...
Cited by 12 Related articles All 4 versions Cite Save

[CITATION] Effect of **roof** shapes on unsteady flow dynamics in street canyons
JF Barlow, B Lenti - International workshop on physical modelling of flow ..., 2007
Cited by 7 Related articles Cite Save

Radiocaesium on urban surfaces after Chernobyl oxfordjournals.org [PDF]
PJ Sandalls - Radiation Protection Dosimetry, 1997 - NTP
... Retention ranged from 3% for hard, semi-glazed **roofing** tiles, to more than 50% for Marley ... from Chernobyl) when heavy rainfall on 2 and 3 May led to **predominantly** wet deposition ... and SDs

http://www.google.com/profiles 100%

... variables were the runoff and the physical-chemical parameters, and rainfall regime predominant wind orientation ... Depending on the local rainfall profile (either **predominance** of small or large rain events ... affect the runoff from M and P **roofs** (the only single **pitch** sloping **roofs**). ...
Cited by 53 Related articles All 10 versions Cite Save

Environmental adaptation and structural design in axially-**pitched** longhouses from Neolithic Europe
A Marshall - World Archaeology, 1981 - Taylor & Francis
... 1700 m, where rectangular longhouses the most widespread Melanesian type, become the **predominant** traditional form ... from Britain and mainland Europe has a mean value of axial **pitch** (x) of ... 4) shows that, during the winter period, the winds are **predominantly** from the south ...
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Detection of adducts of deoxyribonucleic acid in white blood cells of roofers by ^{32}P-postlabeling: Relationship of adduct levels to measures of exposure to polycyclic . . sjweh.fi [PDF]
R Herbert, M Marcus, MS Wolff, FP Perera, . . - Scandinavian journal of . . ., 1990 - JSTOR
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A rational approach to greenhouse design plastiques-agriculture.com [PDF]
BJ Bailey, GM Richardson - II Workshop on Greenhouse Construction . . ., 1989 - actahort.org
... low cost of construction and low operating costs, which, in northern latitudes, is **predominantly** the cost ... for the 25° reference house will increase and the sensitivity of cost to **roof pitch** will also ... the light transmission of a curved **roof** greenhouse was equal to a **pitched roof** house in ...
Cited by 12 Related articles All 4 versions Cite Save

[CITATION] Effect of **roof** shapes on unsteady flow dynamics in street canyons
JF Barlow, S Lalli - International workshop on physical modelling of flow . . ., 2007
Cited by 7 Related articles Cite Save

Radiocaesium on urban surfaces after Chernobyl oxfordjournals.org [PDF]
FJ Sandalls - Radiation Protection Dosimetry, 1997 - NTP
... Retention ranged from 3% for hard, semi-glazed **roofing** tiles, to more than 50% for Marley ... from Chernobyl) when heavy rainfall on 2 and 3 May led to **predominantly** wet deposition ... and SDs 5239±1105 16292±1782 9955 ±2099 Urban surfaces Slates from **pitched roof** fi) Direct ...
Cited by 7 Related articles All 4 versions Cite Save

Structural Dynamics and Response of **Roof** Tiles under Wind Loading
S Okamoto - ASME 2006 Pressure Vessels and . . ., 2006 - . . . asmedigitalcollection.asme.org
... if the element is located in an area with attached flow, eg on the windward surface of a **pitched roof**. ... If the **roof pitch** is increased, the vortex cores decrease in strength. ... The **predominant** geometric parameter for the pressure distribution is the tile thickness related to the non ...
Cited by 5 Related articles All 5 versions Cite Save

A survey of **roof** failures in Oyo State of Nigeria palgrave-journals.com [HTML]
Y Mijinyawa, SO Adesogan, . . - Journal of Building . . ., 2007 - palgrave-journals.com
... The most popular of the **pitch roof** types is the gable **roof**. ... CONCLUSIONS. Although all types of **roof** could be found in the area surveyed, **pitched**/gable **roofs** were the most **predominant** accounting for about 55 per cent, while only about 16 per cent were flat **roofs**. ...
Cited by 3 Related articles All 2 versions Cite Save

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Google predominant pitch roof

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[PDF] Inferences about built form, construction, and fabric in the nondomestic building stock of England and Wales — researchgate.net [PDF]
P Steadman, HR Bruhns, B Gakovic - Environment and Planning ..., 2000 - researchgate.net
... Thus, felt and asphalt as **roof** materials are associated **predominantly** with flat **roofs** or **roofs** with ... The composite classification is given in table 5. 'Double **pitch**' covers both gabled and hipped **roofs** ... analysis takes account, in each case, of which type of **roof** is **predominant** on a ...
Cited by 17 Related articles All 14 versions Cite Save More

[PDF] The passive environment control system of Kerala vernacular residential architecture: an experimental investigation on wind flow and thermal comfort — cafetinnova.org [PDF]
AS Dili, MA Naseer, TZ Varghese - International Journal of Earth ..., 2009 - cafetinnova.org
... **Predominant** wind direction during monsoon period, ie, June to September is west to South west ... Though **predominantly** south west, the wind is influenced by the presence of other topographical features ... The **roofs** have high **pitch** up to 45 degrees to help the rain water drainage ...
Cited by 4 Related articles Cite Save More

Small-scale test behavior of cold-formed steel **roof** trusses
JL Dawe, JV Wood - Journal of structural engineering, 2006 - ascelibrary.org
... With decreasing steel thickness, tilting becomes the **predominant** failure mechanism while bearing stress becomes more ... is always a concern when looking at the performance of a **pitched roof** in areas of ... Each test specimen was constructed at a 4:12 **roof pitch** using CFS C-stud ...
Cited by 5 Related articles All 6 versions Cite Save

Risk assessment of residential buildings for an eruption of Furnas Volcano, Sao Miguel, the Azores — researchgate.net [PDF]
A Pomonis, R Spence, P Baxter - Journal of Volcanology and Geothermal ..., 1999 - Elsevier
... In areas of heavy snowfall **roofs** with **pitch** of 35° or greater are a standard design feature of domestic and other buildings. More than 90% of the buildings with **pitched roof** were found to have a **pitch** of around 30°, and this is also maintained in new buildings. 4.6. ...
Cited by 46 Related articles All 5 versions Cite Save

[CITATION] Louisiana's Remarkable French Vernacular Architecture, 1700-1900
JD Edwards - 1988 - Department of Geography &
Cited by 17 Related articles Cite Save More

Long-term performance of selected old Berlin greenroofs in comparison to younger extensive greenroofs in Berlin — researchgate.net [PDF]
M Köhler, PH Poll - Ecological Engineering, 2010 - Elsevier
... Advantages including reduced cost (due to low **pitch** and fewer required building materials), fire resistance and ... MEG-**roof** placed onto the moderately **pitched** (20° 20 °) original **roof** of a typical 5-story ... In reality the **predominant** wind direction has to be taken into account, too. ...
Cited by 41 Related articles All 3 versions Cite Save

Architecture and Class Segregation in Late Nineteenth-Century Terre Haute, Indiana
RW Bastian - Geographical Review, 1975 - JSTOR
... A still **predominantly** residential remnant of this neighborhood was found to be confined to Terre ... 3). As on the Neo-Jacobean houses, **roofs** are steeply **pitched** and have projecting gables or ... Revival houses have a round French-chateau-style corner tower with a conical **roof**. ...
Cited by 13 Related articles Cite Save

[PDF] Finite Element and Experimental Investigation on Profiled Steel Sheet to Develop Self-supporting **Roofing** Element — docsdrive.com [PDF]

http://scholar.google.com/s... satellite image estimate roo...

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Suggested Sites Forms and Information o... Tea da 101 FAX Cisco After Final Consideration ... Resources uspto

Web Images More... MEZ.com@gmail.com

Google satellite image estimate roof

Scholar About 27,900 results (0.08 sec) Any time

Calculation of bright **roof**-tops for solar PV applications in Dhaka Megacity, Bangladesh
MH Kabir, W Endlicher, J Jagermeyr - Renewable Energy, 2010 - Elsevier
... been done through the Object Based **Image** Analysis (OBIA) from the Quickbird **satellite** data of ... Areas outside the DCC wards of the Quickbird **image** mostly cover water bodies, agricultural lands ... That is why this object-based assessment tool is not useful to **estimate** the overall ...
Cited by 32 Related articles All 8 versions Cite Save

GIS and volcanic risk management gisknowledge.net [PDF]
MT Pareschi, L Cavarra, M Favalli, F Giannini ... - Natural Hazards, 2000 - Springer
... 2.2. DIGITAL **IMAGES** FROM **SATELLITE** OR AIRCRAFT ... the volcano, derived from a map at an original scale of 1 : 25,000 and from remote sensing **images**, are inhabited ... times of 1 min on a PC 200 MHz, 64 MB Ram) superimposed on a shadowed georeferenced **image** of Mt. ...
Cited by 101 Related articles All 10 versions Cite Save

Regularization of RIF blind **image** deconvolution hku.hk [PDF]
MK Ng, RJ Plemmons, S Qiao - Image Processing, IEEE ..., 2000 - ieeexplore.ieee.org
... guide star **image** as initialization and use of a good **estimate** of the support are useful in the blind decon- volution of the **satellite image** ... [8] D. Kundur, "Blind deconvolution of still **images** using recursive ... [15] D. Kundur and D. Hatzinakos, "Blind **image** deconvolution revisited ...
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[BOOK] Remote sensing of impervious surfaces
Q Weng - 2007 - books.google.com
... Sensing of Impervious Surfaces. Qihao Weng Multispectral **Image** Analysis Using ... and Daniele Riccio **Roof** Mapping Using Fused Multiresolution Optical **Satellite Images** ... ... Remotely Sensed Impervious Surface Data to **Estimate** Population ...
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Q Zheng, R Chellappa - Image Processing, IEEE Transactions ..., 1993 - ieeexplore.ieee.org
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An examination of some problems and solutions in monitoring urban areas from **satellite** platforms
SC Forster - International Journal of Remote Sensing, 1985 - Taylor & Francis
... and where the line intersects the vertical axis will represent the additive path radiance effect which will generally vary between **images** because of ... Monitoring urban areas from **satellite** platforms ... BERNSTEIN, R., 1976, Digital **image** processing of Earth observational sensor data. ...
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[PDF] 3D modelling of buildings using laser scanning and spectral information isprs.org [PDF]
T Vogtle, E Steinle - International Archives of Photogrammetry and Remote ..., 2000 - isprs.org
... **Satellite Image** Analysis using Integrated Knowledge Processing. ... **Image** Analysis and Mathematical Morphology. ... In: Grün, A., Baltsavias, EP. Automatic Extraction of Man-Made Objects from Aerial and Space **Images** (II), Proceedings of the Centro Stefano Franscini (Ascona ...
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Hurricane disaster assessments with **image**-driven data mining in high-resolution **satellite** imagery researchgate.net [PDF]
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[PDF] 3D modelling of buildings using laser scanning and spectral information isprs.org [PDF]
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Hurricane disaster assessments with **image**-driven data mining in high-resolution **satellite** imagery researchgate.net [PDF]
CF Barnes, H Fritz, J Yoo - Geoscience and Remote Sensing, ..., 2007 - ieeexplore.ieee.org
... applications of a-tree-based **image** data mines when applied to remotely sensed disaster **images**. ... have been used as a foundation for systems engineering of an **image**-driven information mining capability for disaster assessments in high-resolution **satellite** imagery. ...
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Estimating erosion surface features by linear mixture modeling
GI Metternicht, A Fermont - Remote Sensing of Environment, 1998 - Elsevier
... The median of the abundance **images** showed that, in 95% of the cases, the ... surface feature, were selected in the ephemeral brooks and sampled to **estimate** the proportions of ... the various methods commonly used to determine end-members from the **satellite image**, three were ...
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Per-pixel and object-oriented classification methods for mapping urban features using Ikonos **satellite** data researchgate.net [PDF]
S Bhaskaran, S Paramananda, M Ramnarayan - Applied Geography, 2010 - Elsevier
... We used both raster and vector data (aerial **photo images**, street and road networks, buildings) from ... The first step in the analysis was to segment the **image** into different homogeneous objects ... the optimal segments were **estimated** from a time-series of mss Ikonos **satellite** data by ...
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Results for **satellite image estimate roof predominant pitch** (without quotes):

Aerial Roof Estimating Fast and Accurate | Replacement ...
www.replacementcontractoronline.com/.../roofing/aerial-roof-estimating/...
May 5, 2009 - Roofing contractors make use of a new estimating tool they say is safer and more ... enabling a satellite to pinpoint and photograph that particular roof, and then ... measurements as well as pitched angle measurements and materials lists ... improvement company in Milwaukee, Wis., started using aerial imaging last year.

Satellite Roof Measuring - Page 3 - Roofing - Contractor Talk
www.contractortalk.com › Forum › Trade Talk › Roofing
Mar 29, 2009 - 26 posts - 7 authors
http://www.mapcruzin.com/satellite-aerial-photos-maps/ ... With the oblique views we accurately determine the pitch and the total square is calculated with the ...

Cutting down solar costs with satellite imagery - CNET
www.cnet.com/.../cutting-down-solar-costs-with-satellite-imagery/ - CNET
Apr 16, 2009 - "We do all that (the calculations for preparing the estimate) in about 10 to 15 ... From the model, Sungevity calculates the pitch of the roof, the azimuth (for ...

[PDF] Full text - Simon Fraser University
summit.sfu.ca/system/files/iritems1/12506/etd7493_ZBlair.pdf
by ZD Blair - 2012 - Related articles
Dec 15, 2008 - pitch, from single satellite/aerial images in situations where previous ... 4.3 Rooftop Pitch Estimation ... 4.5 Measuring roof pitch using the Gimp ... edges in the image, the edges from skylights and rooftop vents appear predominantly in.

[PDF] Appearance-Guided Monocular Omnidirectional Visual ...
rpg.ifi.uzh.ch/.../IEEE_TransRobotics_scaramuzza.p... - University of Zurich
by D Scaramuzza - Cited by 164 - Related articles
Nov 14, 2008 - nidirectional camera mounted on the roof of the vehicle. ... estimated purely from omnidirectional images over a distance of ... superimposed onto a satellite image of the same test environment ... is predominant, there are also many feature points that come ... the orientation (roll and pitch angles) of the camera axis in the.

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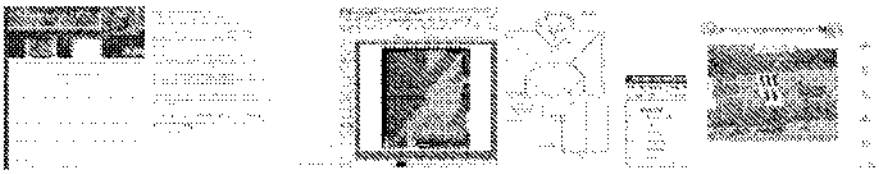
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Aerial Roof Estimating Fast and Accurate | Replacement ...
www.replacementcontractoronline.com/.../roofing/aerial-roof-estimating ...
May 6, 2009 - Roofing contractors make use of a new estimating tool they say is safer and more ... enabling a satellite to pinpoint and photograph that particular roof, and then ... measurements as well as pitched angle measurements and materials lists ... improvement company in Milwaukee, Wis., started using aerial imaging last year.

Satellite Roof Measuring - Page 3 - Roofing - Contractor Talk
www.contractortalk.com › Forum › Trade Talk › Roofing
Mar 29, 2009 - 20 posts - 7 authors
http://www.mapcruzin.com/satellite-aerial-photos-maps/ ... We account for pitch! ... We actually use 6 different images to calculate the area of a given roof.

Images for satellite image estimate roof pitch
Report images



More images for satellite image estimate roof pitch

How It Works - RoofCAD ::: Smart Software for Roofing ...
www.roofcad.com/Satellite/HowItWorksPitched.aspx
Jan 4, 2009 - Acquire a satellite or aerial image of the house from a service like Pictometry, Google Earth ... allow you to calculate the pitch, very accurately, from their images.

Geoestimator... eagle view... etc etc - Roofing.com
talk.roofing.com/t/geoestimator-eagle-view-etc-etc/5307
Feb 27, 2010 - so I was at the roofing convention this week, and all these companies who are doing satellite imaging and full measurements (pitch, ridge, perimeter, sq ft, ... I know that measuring the roof with a tape measure is free, but sometimes its too ...

Cutting down solar costs with satellite imagery - CNET
www.cnet.com/.../cutting-down-solar-costs-with-satellite-imagery/ CNET
Apr 16, 2008 - "We do all that (the calculations for preparing the estimate) in about 10 to 15 ... From the model, Sungevity calculates the pitch of the roof, the azimuth (for ...

Roofr Exhibit 1002, Page 879

Pictometry PictometryOnline™ RT GUIDE

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output in Measurement Display Area in bottom left hand corner. Can be used with the *Walk The Earth* option (in preferences). When Measuring Area or Distance using an angled turn use the Vertex 'V' key (Click and Hold/Drag and tap V at the point of the turn).

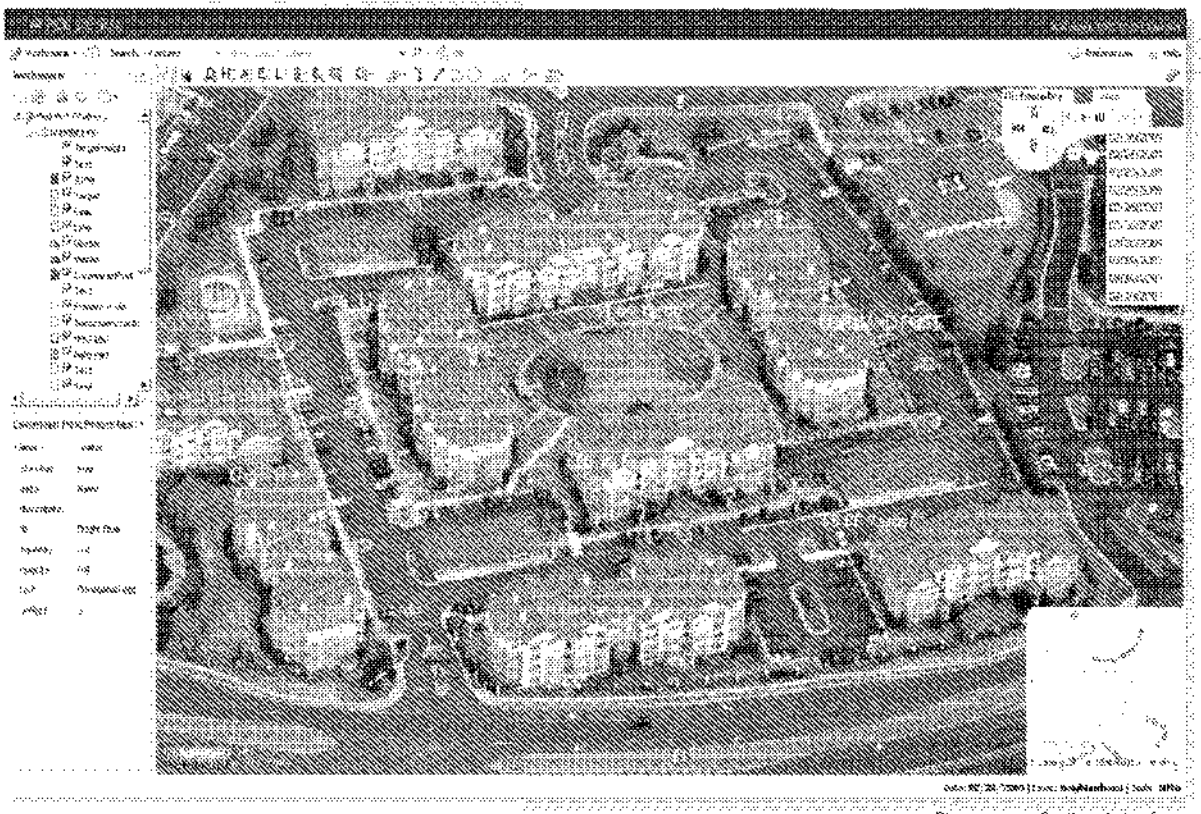
H **HEIGHT TOOL** - Measures the "ground up" height of any building/object seen in an oblique image (see Image Types). *Note:* Always be sure to start at the ground and measure from the ground, up; otherwise, you will end up with an incorrect negative value. See output in Measurement Display Area in bottom left hand corner.

A **AREA TOOL** - Measures area in polygon and free form fashion. To measure a polygon, [Click on corner 1 and Drag to corner 2, then depress and hold CTRL key & drag to corner 3] Free-form lines: [Click+ALT & Drag].

E **ELEVATION TOOL** - Reports the elevation above sea level of a point in the image. See output in Measurement Display area in bottom left hand corner. To see elevation changes click, hold CTRL and drag to second point.

Pictometry

Pictometry Online™ QUICK START GUIDE



Pictometry Online Interface

Measurement Data Tools

PAN TOOL - Seamlessly pan across entire areas.

IMAGE TOOL - Click on any point on the map or an image to redirect your area of interest.

DISTANCE TOOL - Measure straight lines: [Click & Drag]. Measure free-form lines: [Click+ALT & Drag]. See output in Measurement Display Area in bottom left hand corner. Can be used with the *Walk The Earth* option (in preferences). When Measuring Area or Distance using an angled turn use the Vertex "V" key (Click and Hold/Drag and tap V at the point of the turn).

HEIGHT TOOL - Measures the "ground up" height of any building/object seen in an oblique image (see Image Types). *Note:* Always be sure to start at the ground and measure from the ground, up; otherwise, you will end up with an incorrect negative value. See output in Measurement Display Area in bottom left hand corner.

AREA TOOL - Measures area in polygon and free form fashion. To measure a polygon, [Click on corner 1 and Drag to corner 2, then depress and hold CTRL key & drag to corner 3] Free-form lines: [Click+ALT & Drag].

ELEVATION TOOL - Reports the elevation above sea level of a point in the image. See output in Measurement Display area in bottom left hand corner. To see elevation changes click, hold CTRL and drag to second point.

LOCATION TOOL - Reports the lat/long coordinates in the Measurement Display Area in bottom left hand corner.

BEARING TOOL - Easily find compass bearing and interior angle.

ROOF PITCH TOOL - Measures roof heights, area, slope and roof pitch.

Query and Annotation Tools

EXTRACT TOOL - Crop and save images and annotations to a file.

QUERY TOOL - GIS data layers seamlessly integrate into POL and can be queried by selecting a layer from the dropdown then clicking on the image.

MARKER TOOL - Mark any image with a variety of symbols and markers.

TEXT TOOL - Type and edit text right on your image.

LINE TOOL - Create lines that vary in thickness and color.

SHAPE TOOL - Create any enclosed linear polygon.

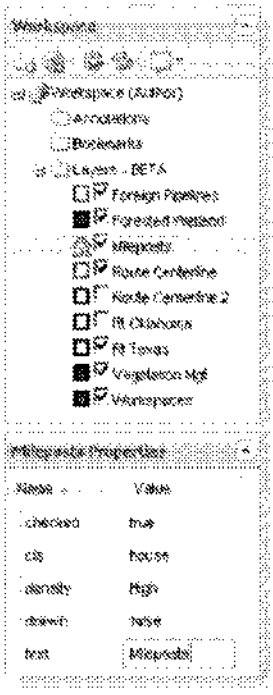
CIRCLE TOOL - Create a circle by clicking on the center point, followed by clicking on the radius point.

LINE COLOR - Choose from a variety of predetermined or custom colors.

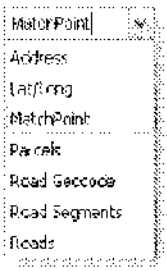
FILL COLOR - Choose from a variety of predetermined or custom colors.

CLEAR TEMPORARY ANNOTATIONS - Easily erase temporary annotations such as measurements and GIS queries.

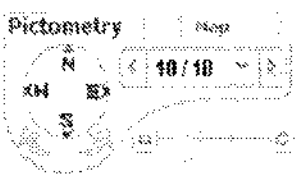
EXPORT CURRENT IMAGE - Export screen image or entire native image.



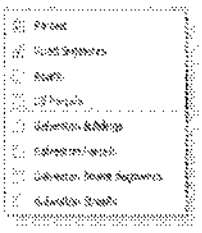
WORKSPACE - Keep all your annotations, bookmarks and queries organized in folders and instantly share vital visual intelligence and annotations with multiple users from multiple locations.



SEARCH - Multiple search options are available to accurately locate any point, address, coordinates, parcel, road, centroid or landmark.



NAVIGATE - Quickly and easily view Pictometry obliques, orthos and change to detailed bing 2D maps.



QUERY TOOL - GIS data layers seamlessly integrate into POL and can be queried by clicking on any available layer.

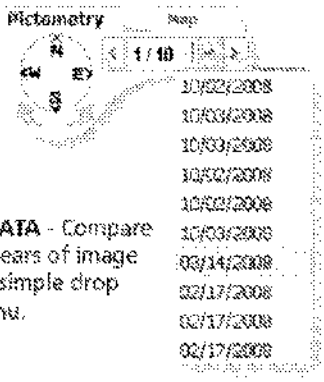


IMAGE DATA - Compare multiple years of image data by a simple drop down menu.

Image Types and Image Levels

Orthogonal – These images are taken from a straight down perspective, producing a *flat* "roof top" image.

Oblique – These images are taken from approximately a 45-degree perspective, producing an "3D-like" image.

Neighborhood - Lower altitude producing the greatest detail of the displayed ground area.

Community - Higher altitude images providing a larger "footprint" of the displayed ground area.

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	181	((predominant primary average estimat$3) near pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:55
L3	6	(predominant adj pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:55
L4	6	(predominant adj pitch) with roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:56
L6	17	(thornberry near2 chris).in. (thornberry near2 dale).in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:56
L8	93	pictometry.as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:59
L10	28	(6 8) and pitch and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/06/23 12:59
S6	1	13/424054	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:17
S7	10	"20100179787" "20100110074"	US-PGPUB;	OR	ON	2014/04/10

Roofr Exhibit 1002, Page 883

		"20100114537" "20100187715" "8078436".pn. 12/090692	US-PGPUB; USPAT			17:33
S9	21	aerial adj roof adj estimat$4	US-PGPUB; USPAT	OR	ON	2014/04/10 17:35
S10	4	(US-20100114537-$ or US-20100179787-$ or US-20100110074-$).did. or (US-8078436-$).did.	US-PGPUB; USPAT	OR	ON	2014/04/10 17:37
S11	23	predominant adj pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S12	0	S10 and S11	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:37
S13	3	(predominant adj pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:38
S14	4	S10 and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:39
S15	8079	pitch near4 averag$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S16	0	S10 and S15	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S17	1	S15 and S7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/10 17:42
S18	2	"20100114537" and pitch	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2014/04/10 21:51

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			EPO; JPO; DERWENT; IBM_TDB			
S19	5	"8078436".pn. "8145840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S20	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:46
S21	5	"8078436".pn. "8170840".pn. "8209152".pn. "8515198".pn. "8401222".pn.	US-PGPUB; USPAT	OR	ON	2014/04/11 16:47
S22	2	"20100296693"	US-PGPUB; USPAT	OR	ON	2014/04/11 16:48
S23	2	"20100296693" and pitch	US-PGPUB; USPAT	OR	ON	2014/04/11 16:49
S24	1	"20130246204" and (pitch same averag$3)	US-PGPUB; USPAT	OR	ON	2014/04/11 16:58
S25	0	"20100296693" and footprint	US-PGPUB; USPAT	OR	ON	2014/04/11 21:30
S26	2	"20100296693" and computer	US-PGPUB; USPAT	OR	ON	2014/04/11 21:45
S27	2	"20100296693" and edge	US-PGPUB; USPAT	OR	ON	2014/04/11 21:53
S28	2	"20100296693" and oblique	US-PGPUB; USPAT	OR	ON	2014/04/11 21:54
S29	2	"20100296693" and orientation	US-PGPUB; USPAT	OR	ON	2014/04/11 21:55
S30	2	"20100296693" and automatic	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 21:57
S31	2	"20100296693" and automatic$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 21:57
S32	2	"20100296693" and (seller contrator retailer merchant vendor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:01
S33	22521	705/26.1-27.2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S34	11	(thornberry near2 chris).in. (thornberry near2 dale).in.	US-PGPUB; USPAT;	OR	ON	2014/04/11 22:06

Roofr Exhibit 1002, Page 885

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S35	45261	(image and roof)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S36	10	S34 and S35	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:06
S37	2	"20060200311"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:08
S38	372	(find$3 locat$3 determin$3) with (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
S39	171240	"705".clas.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
S40	108	S38 and S39	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:10
S41	38	(find$3 locat$3 determin$3) adj2 (contractor near3 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S42	7	(find$3 locat$3 determin$3) adj2 (contractor adj2 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11

Roofr Exhibit 1002, Page 886

S43	31	(find$3 locat$3 determin$3) adj2 (contractor adj5 location)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S44	17	S39 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:11
S45	1	"20020087332" and location	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:14
S46	17755	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:24
S47	596	(estimat$3 same roof$3 same (size area footprint))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:24
S48	5	S46 and S47	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S49	99	(estimat$3 same roof$3 same (size area footprint)) and aerial	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S50	1	S46 and S49	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/04/11 22:25
S59	17	"8078436".pn. "8145578".pn. "8170840".pn. "8209152".pn. "8515125".pn. "8515198".pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2014/11/20 17:51

Roofr Exhibit 1002, Page 887

			DERWENT; IBM_TDB			
S60	0	(predominant adj pitch) and S59	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:54
S61	664	((predominant primary) adj2 pitch) near2 pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:57
S62	10	((predominant primary) adj2 pitch) near2 roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:57
S63	8	S59 and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 17:58
S64	2	13/424054 and pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:04
S65	0	roof same (pitch same (area near2 (percent percentage))same (sum add adding! added!) same weight$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:17
S66	34	roof same pitch same area same (weight$3 (percent percentage)) same (sum add adding! added!)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:17
S67	5	roof same area same (weight$3 near4 pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:20
S68	13	roof same (estimat$3 near2 area) same pitch	US-PGPUB; USPAT; USOCR;	OR	ON	2014/11/20 18:21

Roofr Exhibit 1002, Page 888

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S69	17	12/467,244	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:23
S70	6	"20060036513"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:30
S71	14	roof same (average adj pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:39
S72	70	pitch and (slope adj factor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:47
S73	8	roof and pitch and (slope adj factor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:47
S74	1	"20130246204" and "slope factor"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 18:52
S76	2	geoestimator	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:24
S77	2	S76 and (pitch area)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:25
S78	0	eagleview and predominant	US-PGPUB;	OR	ON	2014/11/20

Roofr Exhibit 1002, Page 889

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			20:42
S79	0	eagleview and primary adj pitch	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:42
S80	11	eagleview and ((determin$3 calculat$3 estimat$3) near2 pitch)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:43
S81	3	eagleview and ((determin$3 calculat$3 estimat$3) near2 pitch).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:46
S82	14817	703/1-2.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 20:47
S84	581	("2273876" | "20020041328" | "20020041717" | "20020114536" | "20030014224" | "20030043824" | "20030088362" | "20030214585" | "20040105090" | "20040167709" | "20050073241" | "20050169521" | "20060028550" | "20060036513" | "20060092043" | "20060238383" | "20060250515" | "20070024612" | "20070046448" | "20070237420" | "20080120031" | "20080123994" | "20090177458" | "20090208095" | "20090259568" | "20090304227" | "20100296693" | "20110033110" | "3153784" | "3594556" | "3614410" | "3621326" | "3661061" | "3716659" | "3725563" | "3864513" | "3866602" | "3877799" | "4015080" | "4044879" | "4184711" | "4240108" | "4281354" | "4344683" | "4360876" | "4382678" | "4387056" | "4396942" | "4463380" | "4489322" | "4490742" | "4491399" | "4495500" | "4527055" | "4543603" | "4586138" | "4635136" | "4653136" | "4673988" | "4686474" | "4688092" | "4689748" | "4707698" | "4758850" | "4805033" | "4807024" | "4814711" | "4814896" | "4843463" | "4899296" |	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:45

Roofr Exhibit 1002, Page 890

		"4906198" | "4955227" | "4956872" | "5034812" | "5086314" | "5121222" | "5138444" | "5155597" | "5164825" | "5166789" | "5191174" | "5200793" | "5210586" | "5231435" | "5247356" | "5251037" | "5265173" | "5267042" | "5270756" | "5296884" | "5335072" | "5342999" | "5345086" | "5353055" | "5369443" | "5402170" | "5414462" | "5467271" | "5481479" | "5486948" | "5506644" | "5508736" | "5555018" | "5604534" | "5617224" | "5633946" | "5668593" | "5677515" | "5798786" | "5835133" | "5841574" | "5844602" | "5852753" | "5894323" | "5899945" | "5963664" | "6037945" | "6088055" | "6094215" | "6097854" | "6108032" | "6130705" | "6157747" | "6167300" | "6222583" | "6236886" | "6256057" | "6373522" | "6421610" | "6434280" | "6597818" | "6639596" | "6711475" | "6731329" | "6747686" | "6810383" | "6816819" | "6826539" | "6829584" | "6834128" | "6876763" | "7009638" | "7018050" | "7046401" | "7061650" | "7065260" | "7123382" | "7127348" | "7133551" | "7142984" | "7184072" | "7233691" | "7262790" | "7348895" | "7424133" | "7509241" | "7728833" | "7832267" | "7844499" | "8078396" | "8705843").PN.				
S85	151	((predominant primary average estimat$3) near pitch) and roof	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:46
S86	0	S84 and S85	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/20 21:46

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L2	94	((predominant primary average estimat$3) near pitch) and roof	USPAT; UPAD	OR	ON	2015/06/23 12:55
L5	0	(predominant adj pitch) with roof	USPAT; UPAD	OR	ON	2015/06/23 12:56
L7	4	(thornberry near2 chris).in. (thornberry near2 dale).in.	USPAT; UPAD	OR	ON	2015/06/23 12:56
L9	30	pictometry.as.	USPAT; UPAD	OR	ON	2015/06/23 12:59
S51	6384	705/26.1-27.2.ccls.	USPAT; UPAD	OR	ON	2014/04/11 22:06
S52	3	(thornberry near2 chris).in. (thornberry	USPAT;	OR	ON	2014/04/11

Roofr Exhibit 1002, Page 891

		near2 dale).in.	UPAD			22:07
S53	13851	(image and roof)	USPAT; UPAD	OR	ON	2014/04/11 22:07
S54	3	S52 and S53	USPAT; UPAD	OR	ON	2014/04/11 22:07
S55	0	"20060200311"	USPAT; UPAD	OR	ON	2014/04/11 22:08
S56	3932	705/26.1,26.5,27.1.ccls. G06Q30/0621 G06Q30/0641	USPAT; UPAD	OR	ON	2014/04/11 22:24
S57	172	(estimat$3 same roof$3 same (size area footprint))	USPAT; UPAD	OR	ON	2014/04/11 22:25
S58	1	S56 and S57	USPAT; UPAD	OR	ON	2014/04/11 22:25
S75	5	roof same (average adj pitch)	USPAT; UPAD	OR	ON	2014/11/20 18:40
S83	5358	703/1-2.ccls.	USPAT; UPAD	OR	ON	2014/11/20 20:47

6/ 23/ 2015 1:00:16 PM
C:\ Users\ mzimmerman1\ Documents\ EAST\ Workspaces\ 13424054.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13424054	THORNBERRY ET AL.
	Examiner	Art Unit
	MATTHEW ZIMMERMAN	3684

CPC- SEARCHED		
Symbol	Date	Examiner
G06Q30/0621	4/11/2014	MZ
G06Q30/0641	4/11/2014	MZ

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
705	26.1,26.5,27.1	4/11/2014	MZ

SEARCH NOTES		
Search Notes	Date	Examiner
Updated EAST search and searched inventor and asignee.	6/23/2015	MZ
Searched GOOGLE.	6/23/2015	MZ

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
705	26.1,27.1,26.5	4/11/2014	MZ

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

30589 7590 07/08/2015
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273 2885, on the date indicated below.

Marc A. Brockhaus	(Depositor's name)
Marc Brockhaus	(Signature)
10/07/2015	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO	CONFIRMATION NO.
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	7006

TITLE OF INVENTION: Method and System for Quick Square Roof Reporting

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	10/08/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
ZIMMERMAN, MATTHEW E	3684	705-026100

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 DUNLAP CODDING, P.C.
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Pictometry International Corp.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Rochester, New York

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
- ■ Issue Fee
- ■ Publication Fee (No small entity discount permitted)
- ☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ☐ A check is enclosed.
- ■ Payment by credit card. Form PTO-2038 is attached.
- ☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)
- ☐ Applicant certifying micro entity status. See 37 CFR 1.29 — NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ☐ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status
- ☐ Applicant changing to regular undiscounted fee status. — NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature: Marc Brockhaus Date: 10/07/2015

Typed or printed name: Marc A. Brockhaus Registration No. 40,923

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	13424054
Filing Date:	19-Mar-2012
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Filer:	Marc Alan Brockhaus/Lori Radford
Attorney Docket Number:	6338.157

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	2501	1	480	480

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	480

Electronic Acknowledgement Receipt

EFS ID:	23720000
Application Number:	13424054
International Application Number:	
Confirmation Number:	7006
Title of Invention:	Method and System for Quick Square Roof Reporting
First Named Inventor/Applicant Name:	Chris T. Thornberry
Customer Number:	30589
Filer:	Marc Alan Brockhaus/Lori Radford
Filer Authorized By:	Marc Alan Brockhaus
Attorney Docket Number:	6338.157
Receipt Date:	07-OCT-2015
Filing Date:	19-MAR-2012
Time Stamp:	15:51:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$480
RAM confirmation Number	2523
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	6338157_Transmittal10072015.pdf	55303 77da0700c6790194f1a11dac414997d22a d1b0b	no	1
Warnings:					
Information:					
2	Issue Fee Payment (PTO-85B)	6338157_PartB.pdf	74095 [illegible]	no	1
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30594 [illegible]	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	159992		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Doc Code: TRAN.LET

Document Description: Transmittal Letter

PTO/SB/21 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew Zimmerman
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please Identify below):
  See Remarks

Remarks

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1. SB21 Transmittal Form (1 pg); and
2. PTOL-85 (1 pg).

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Firm Name	DUNLAP CODDING, P.C.		
Signature	Marc Brockhaus		
Printed name	Marc A. Brockhaus		
Date	10/07/2015	Reg. No.	40,923

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Signature	Marc Brockhaus		
Typed or printed name	Marc A. Brockhaus	Date	10/07/2015

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/424,054	11/10/2015	9183538	6338.157	7006

30589 7590 10/21/2015

DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 334 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Chris T. Thornberry, Indianapolis, IN;
Dale R. Thornberry, Carmel, IN;

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY.DOCKET NO./TITLE	REQUEST ID
13/424,054	03/19/2012	Chris T. Thornberry	6338.157	66105

Acknowledgement of Loss of Entitlement to Entity Status Discount

The entity status change request below filed through Private PAIR on 06/19/2018 has been accepted.

CERTIFICATIONS:

Change of Entity Status:

X Applicant changing to regular undiscounted fee status.

NOTE: Checking this box will be taken to be notification of loss of entitlement to small or micro entity status, as applicable.

This portion must be completed by the signatory or signatories making the entity status change in accordance with 37 CFR 1.4(d)(4).

Signature:	/marcabrockhaus/
Name:	Marc A. Brockhaus
Registration Number:	40923

AO 120 (Rev. 08/10)

TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
Mail Stop 8 Director of the U.S. Patent and Trademark Office P.O. Box 1450 Alexandria, VA 22313-1450	

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court for the District of Delaware on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	12/29/2021	for the District of Delaware

PLAINTIFF	DEFENDANT
PICTOMETRY INTERNATIONAL CORP.	ROOFR INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 9,183,538 B2	11/10/2015	Pictometry International Corp.
2	US 10,648,800 B2	5/12/2020	Pictometry International Corp.
3			
4			
5			

In the above---entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
3		
4		
5		

In the above---entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1---Upon initiation of action, mail this copy to Director Copy 3---Upon termination of action, mail this copy to Director
Copy 2---Upon filing document adding patent(s), mail this copy to Director Copy 4---Case file copy

AO 120 (Rev. 08/10)

TO:	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK
Mail Stop 8 **Director of the U.S. Patent and Trademark Office** **P.O. Box 1450** **Alexandria, VA 22313-1450**	

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court for the District of Delaware on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
1:21-cv-01852-RGA	12/29/2021	for the District of Delaware

PLAINTIFF	DEFENDANT
EAGLE VIEW TECHNOLOGIES, INC., and PICTOMETRY INTERNATIONAL CORP.,	ROOFR INC.

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 9,183,538 B2	11/10/2015	Pictometry International Corp.
2	US 10,648,800 B2	5/12/2020	Pictometry International Corp.
3			
4			
5			

In the above entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☑ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading		
	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 8,170,840 B2	5/1/2012	Eagle View Technologies, Inc.
2			
3			
4			
5			

In the above entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director Copy 3—Upon termination of action, mail this copy to Director
Copy 2—Upon filing document adding patent(s), mail this copy to Director Copy 4—Case file copy

PTO/AIA/81 (07-12)
Approved for use through 11/30/2014. OMB 0651-0035
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

■ Practitioners associated with Customer Number: 30589

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

■ The address associated with Customer Number: 30589

OR

☐ Firm or Individual Name: DUNLAP CODDING, P.C.

Address: P.O. Box 16370

City: Oklahoma City | State: OK | Zip: 73113

Country: US

Telephone: 405-607-8600 | Email: mbrockhaus@dunlapcodding.com

Assignee Name and Address: Pictometry International Corp.
25 Methodist Hill Drive
Rochester, NY 14623

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of the practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	9/10/21
Name	Kim Nakamaru	Telephone	(585)373-3777
Title	General Counsel, Pictometry International Corp.		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to be filed by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/21 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Total Number of Pages in This Submission

Application Number	13/424,054
Filing Date	03/19/2012
First Named Inventor	Chris T. Thornberry
Art Unit	3684
Examiner Name	Matthew E. Zimmerman
Attorney Docket Number	6338.157

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☐ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☑ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) _____
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC (Appeal Notice, Brief, Reply Brief)
- ☐ Proprietary Information
- ☐ Status Letter
- ☑ Other Enclosure(s) (please identify below):
  See Remarks

Remarks

ELECTRONICALLY TRANSMITTED:
1. SB21 Transmittal Form (1 pg); and
2. Power of Attorney (1 pg)

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	DUNLAP CODDING, P.C.		
Signature	/Ann M. Robl/		
Printed name	Ann M. Robl		
Date	08/12/2022	Reg. No.	71,541

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature	/Ann M. Robl/		
Typed or printed name	Ann M. Robl	Date	08/12/2022

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES
PATENT AND TRADEMARK OFFICE

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ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
13/424,054	08/12/2022 11:00:59 AM ET	6338.157

Title of Invention

Method and System for Quick Square Roof Reporting

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	9183538
CONFIRMATION #	7006	FILED BY	Lori Martin
PATENT CENTER #	60867838	FILING DATE	03/19/2012
CUSTOMER #	30589	FIRST NAMED INVENTOR	Chris T. Thornberry
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	ANN ROBL

Documents

TOTAL DOCUMENTS: 2

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
6338157_Transmittal.pdf	1	Transmittal Letter	153 KB
6338157_POA.pdf	1	Power of Attorney	296 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
6338157_Transmittal.pdf	90683A6040149697CF339B490D0686B5124DBB2F4789D2456B5197E9698532DFEB1D7A964D8EE89720018D955185A9ABB066A805235C1DB95E7CB9C9A8E15573

6338157_POA.pdf

3DB9A73728D4F520435EA550FABF85A41ADEC96DFC77C9771
03DB22C7178FEA6DB25A87465C7C378131F3B1AC8668400975
6077A3300545EFEFC6F1AB80D0A27

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/424,054	03/19/2012	Chris T. Thornberry	6338.157

CONFIRMATION NO. 7006

30589
DUNLAP CODDING, P.C.
PO BOX 16370
OKLAHOMA CITY, OK 73113

POA ACCEPTANCE LETTER

OC000000135855079

Date Mailed: 08/17/2022

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/12/2022.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/tnwilliams/

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FEE ADDRESS CHANGE

APPLICATION #	FILING OR 371(C) DATE	REQUEST ID
13/424,054	03/19/2012	39392

The following fields have been changed to Customer Number 189081 on 09/01/2022 via Patent Center in view of the certification copied below that authorized the change.

- Maintenance Fee Address

The address for Customer Number 189081 is:

189081 - EagleView
PO BOX 16370
OKLAHOMA CITY, OK 73113

I certify, in accordance with 37 CFR 1.4(d)(4), that I am :

An attorney or Agent of Record registered to practice before the Patent and Trademark Office who has been given power of attorney in this application

Signature	Name	Registration #
/Ann Robl/	ANN ROBL	71541

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
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www.uspto.gov

CORRESPONDENCE ADDRESS CHANGE

APPLICATION #	FILING OR 371(C) DATE	REQUEST ID
13/424,054	03/19/2012	39392

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PO BOX 16370
OKLAHOMA CITY , OK 73113

I certify, in accordance with 37 CFR 1.4(d)(4), that I am :

An attorney or Agent of Record registered to practice before the Patent and Trademark Office who has been given power of attorney in this application

Signature	Name	Registration #
/Ann Robl/	ANN ROBL	71541