US009135737B2

(12) **United States Patent**
Pershing

(10) **Patent No.: US 9,135,737 B2**
(45) **Date of Patent: *Sep. 15, 2015**

(54) **CONCURRENT DISPLAY SYSTEMS AND METHODS FOR AERIAL ROOF ESTIMATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/450,108**

(22) Filed: **Aug. 1, 2014**

(65) **Prior Publication Data**

US 2015/0015605 A1 Jan. 15, 2015

Related U.S. Application Data

(63) Continuation of application No. 13/474,504, filed on May 17, 2012, now Pat. No. 8,825,454, which is a continuation of application No. 12/467,250, filed on May 15, 2009, now Pat. No. 8,209,152.

(60) Provisional application No. 61/197,904, filed on Oct. 31, 2008.

(51) **Int. Cl.**
G06F 17/50 (2006.01)
G06F 17/10 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06T 11/60*** (2013.01); ***G06F 17/5004*** (2013.01); ***G06K 9/00637*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... G06F 17/20; G06F 17/5004; G06T 7/0042; G06T 7/0083; G06T 2200/24; G06T 2207/30184; G06T 2207/10032; G06K 9/00637
USPC 703/1
See application file for complete search history.

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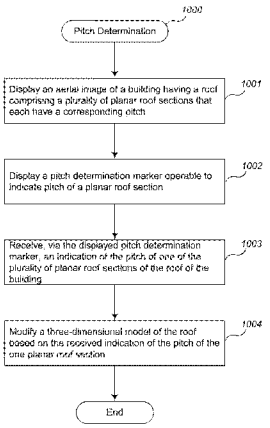
(57) **ABSTRACT**

User interface systems and methods for roof estimation are described. Example embodiments include a roof estimation system that provides a user interface configured to facilitate roof model generation based on one or more aerial images of a building roof. In one embodiment, roof model generation includes image registration, image lean correction, roof section pitch determination, wire frame model construction, and/or roof model review. The described user interface provides user interface controls that may be manipulated by an operator to perform at least some of the functions of roof model generation. The user interface is further configured to concurrently display roof features onto multiple images of a roof. This abstract is provided to comply with rules requiring an abstract, and it is submitted with the intention that it will not be used to interpret or limit the scope or meaning of the claims.

37 Claims, 29 Drawing Sheets



NEARMAP-1001

(51) **Int. Cl.**

G06F 7/60	(2006.01)
G06T 11/60	(2006.01)
G06T 7/00	(2006.01)
G06T 17/20	(2006.01)
G06K 9/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G06T7/0075*** (2013.01); ***G06T 17/20*** (2013.01); *G06T 2207/10012* (2013.01); *G06T 2207/30184* (2013.01)

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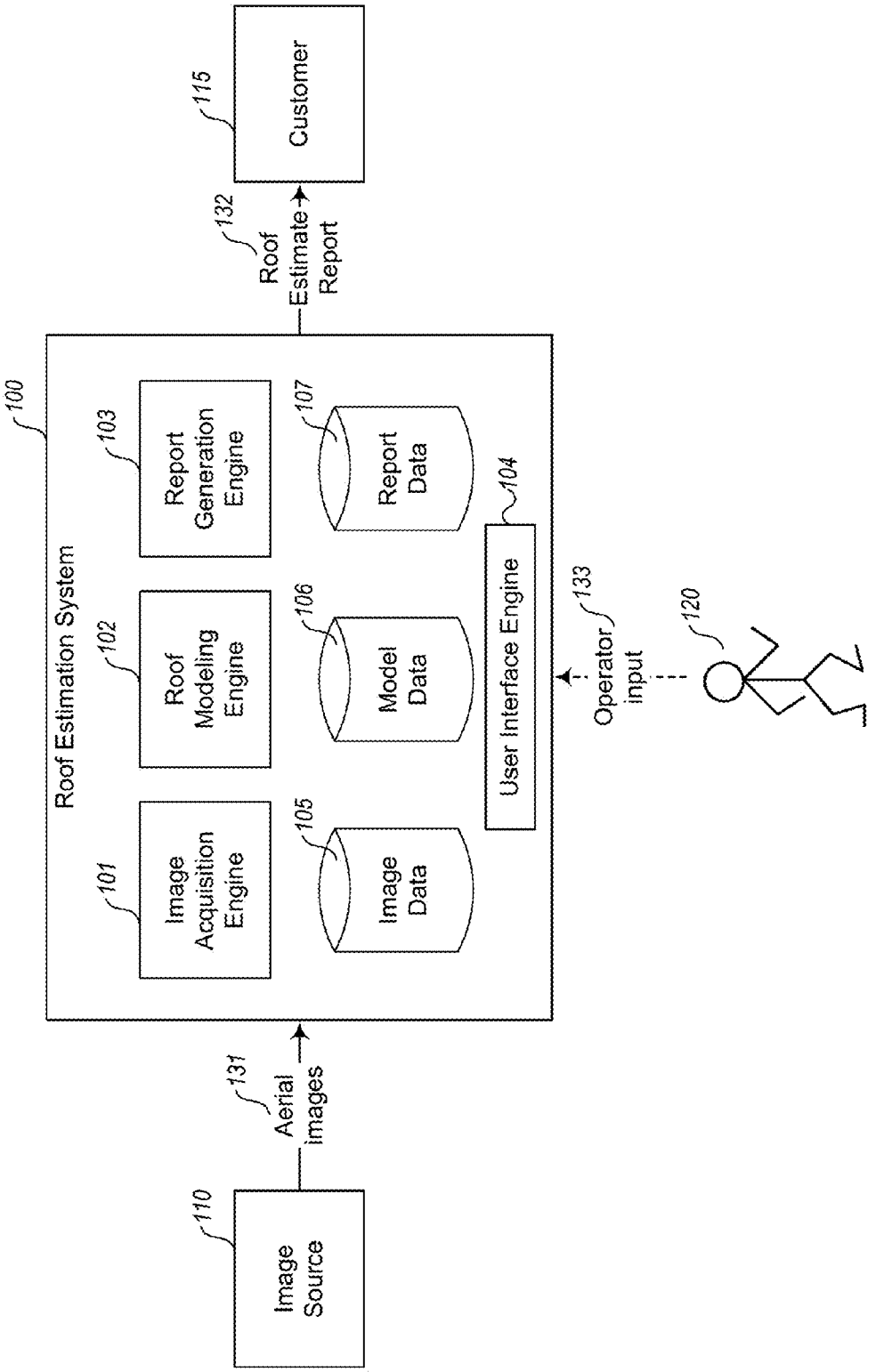
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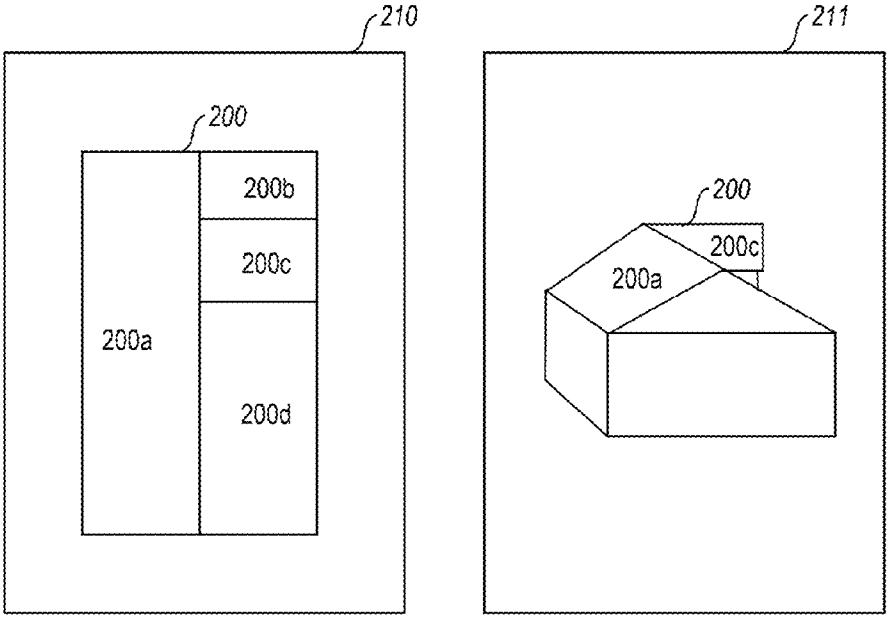
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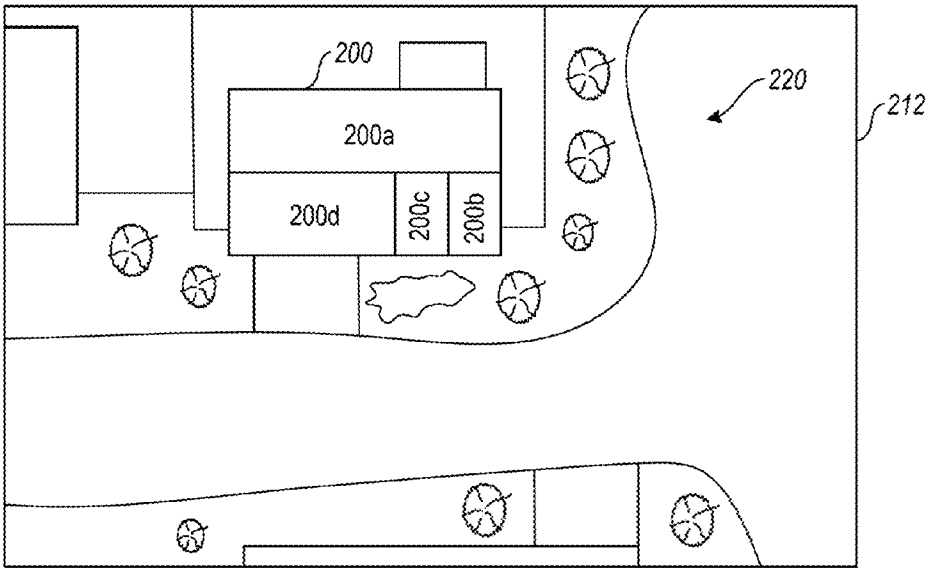
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1234 Main Street, Redmond, WA

301b

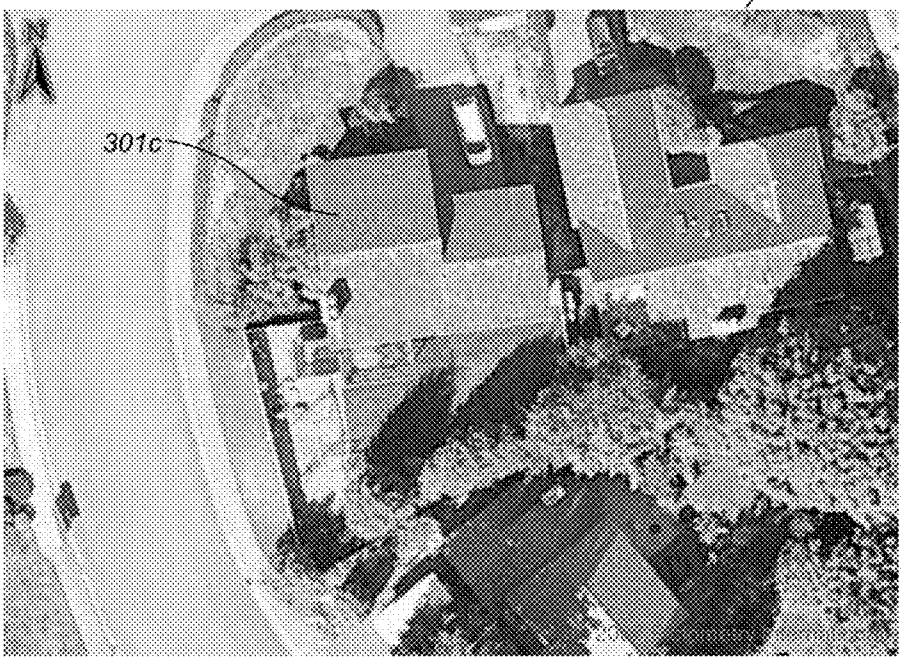

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Fig. 3A

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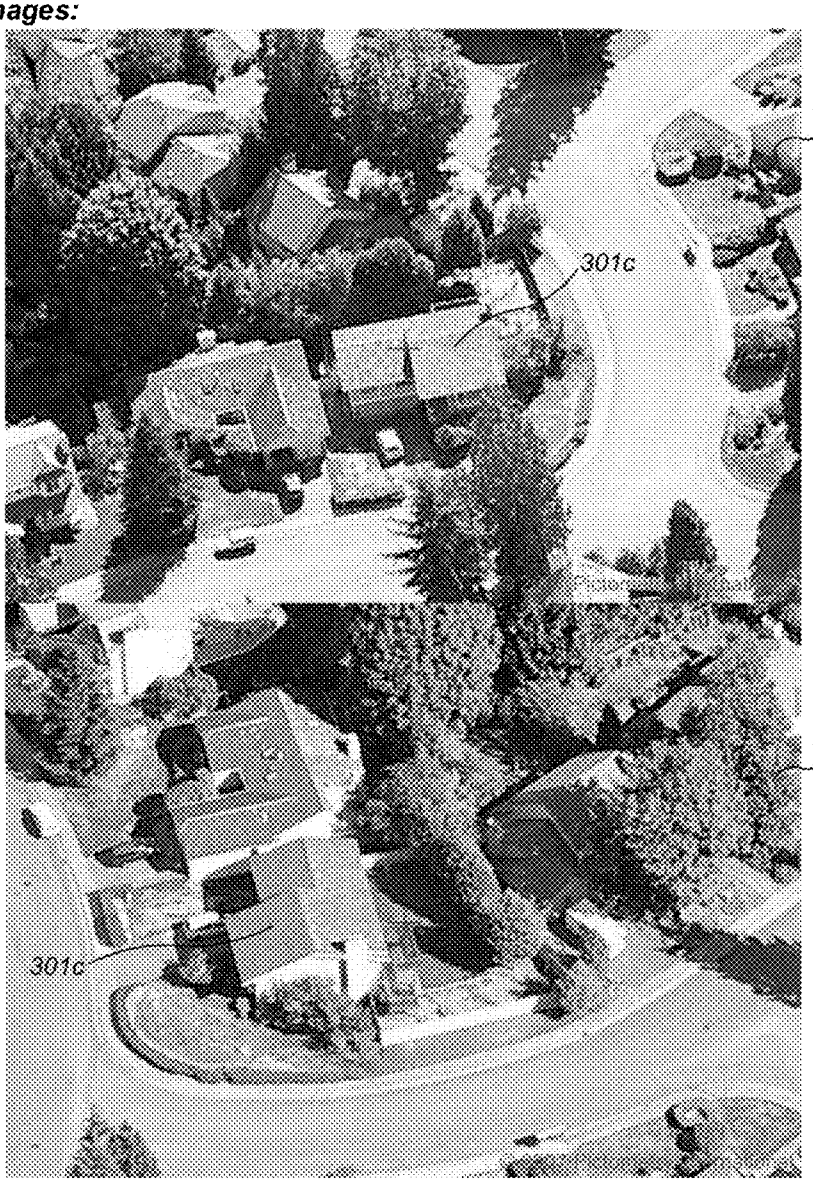

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Fig. 3B

1234 Main Street, Redmond, WA

Length Diagram:
All measurements are rounded to the nearest foot
Ridge Length = 55 ft [Red Lines]
Valley Length = 0 ft [Blue lines]

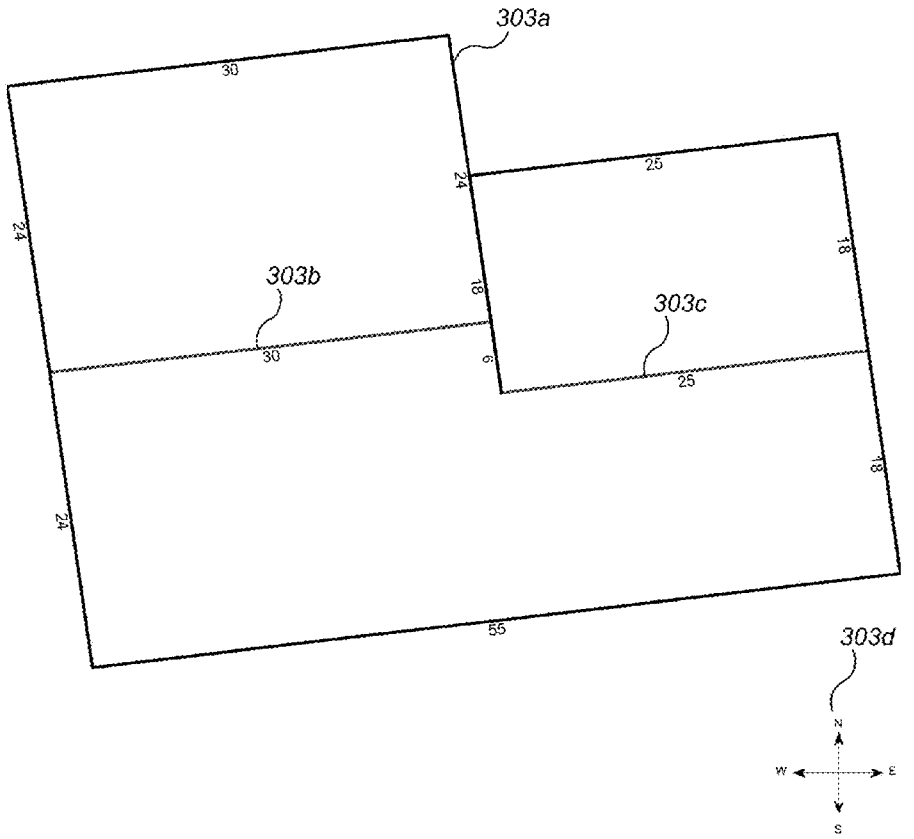

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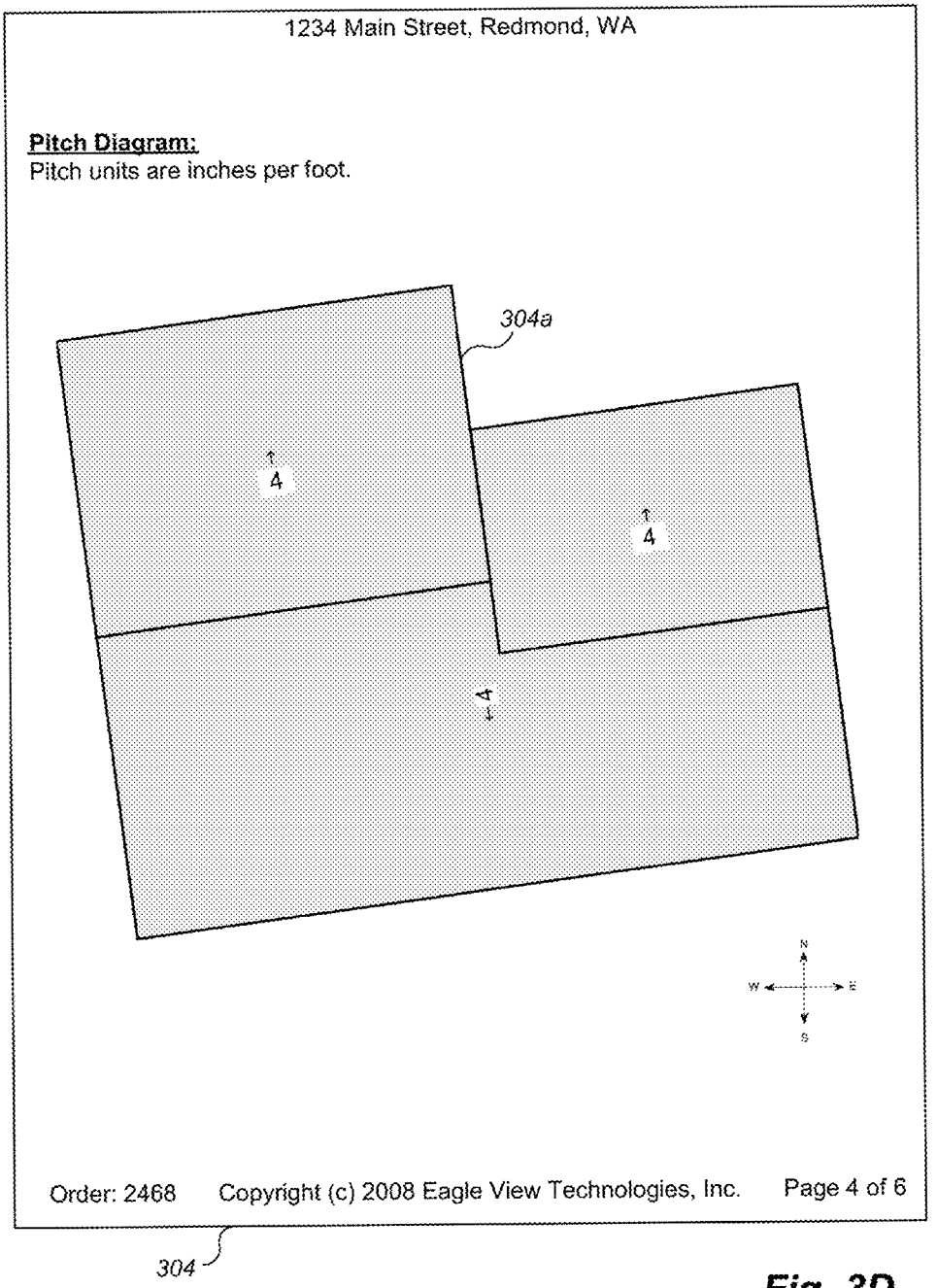
Fig. 3C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Pitch units are inches per foot.
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4
4
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N
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E
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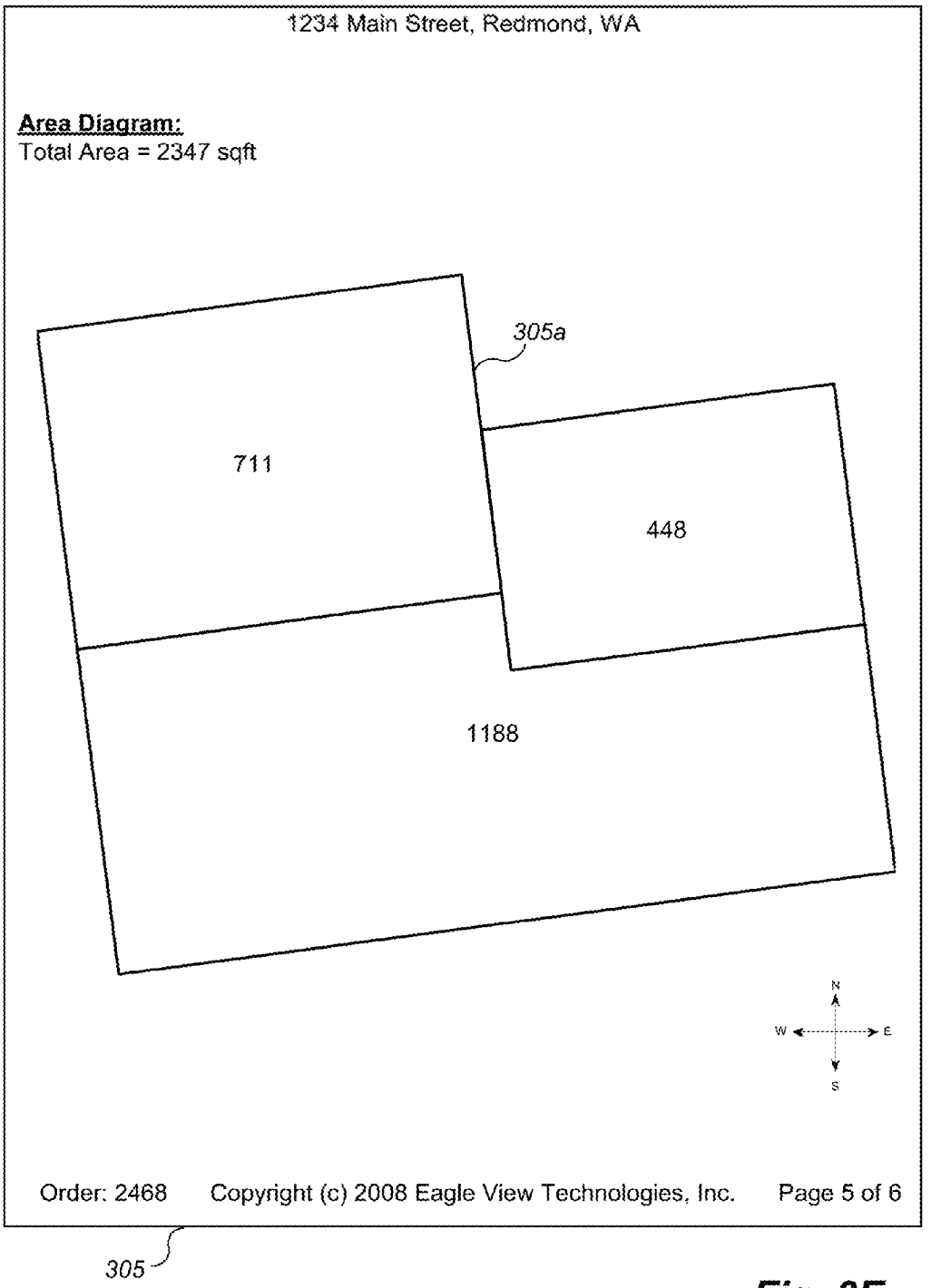
Order: 2468
Copyright (c) 2008 Eagle View Technologies, Inc.
Page 4 of 6
304

Fig. 3D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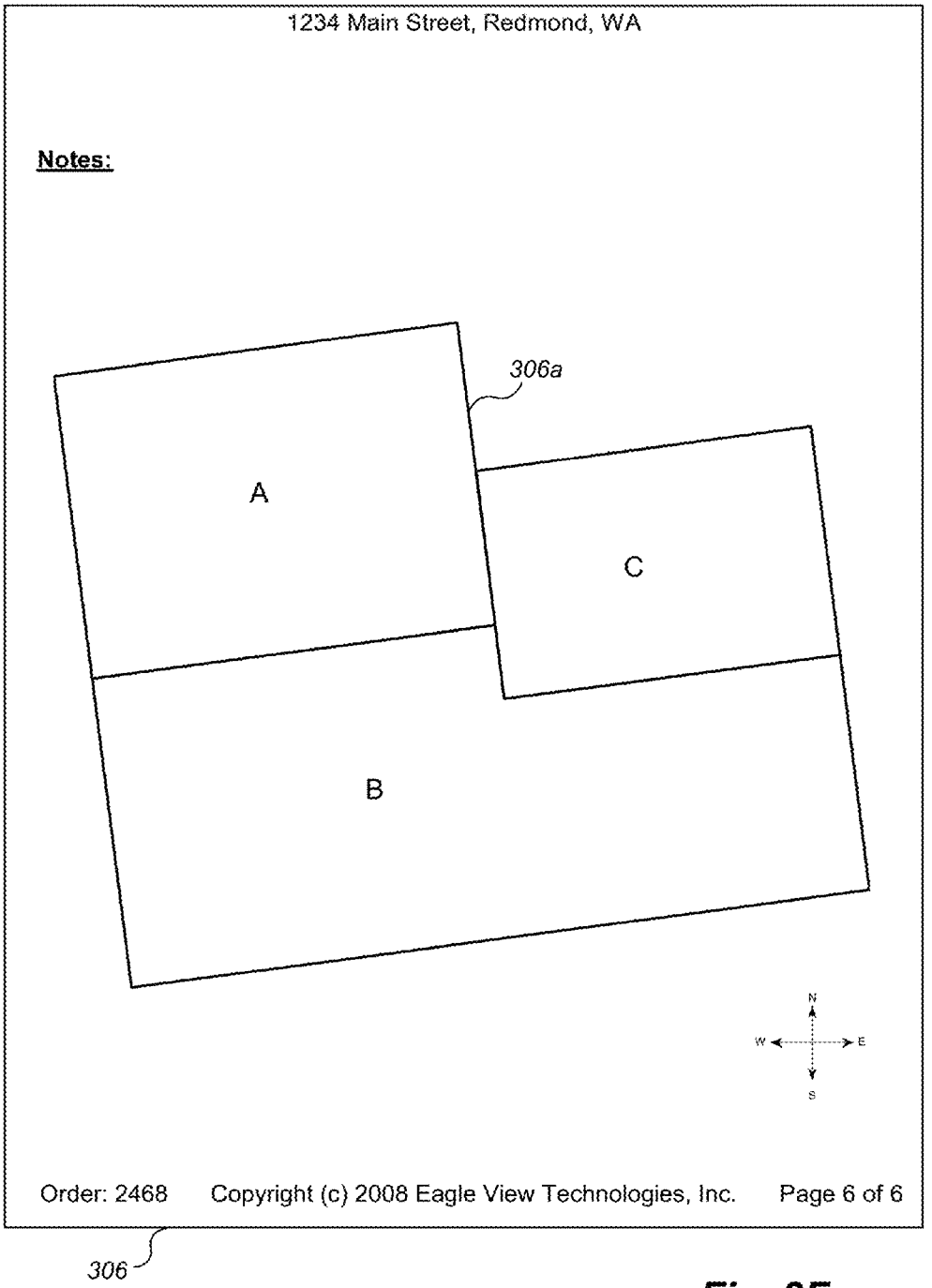
Copyright (c) 2008 Eagle View Technologies, Inc.
Page 5 of 6
305

Fig. 3E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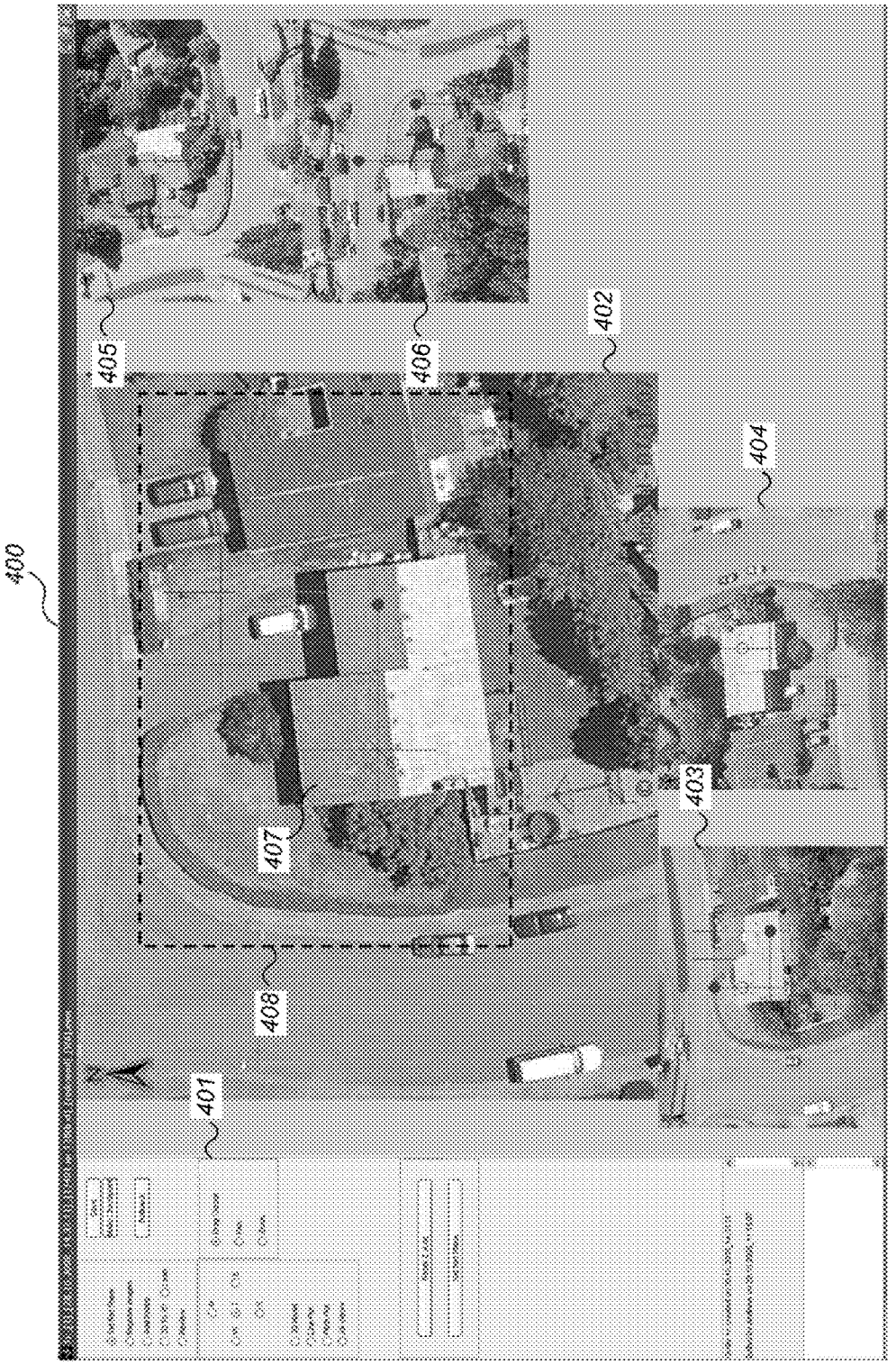
Copyright (c) 2008 Eagle View Technologies, Inc.
Page 6 of 6
306

Fig. 3F



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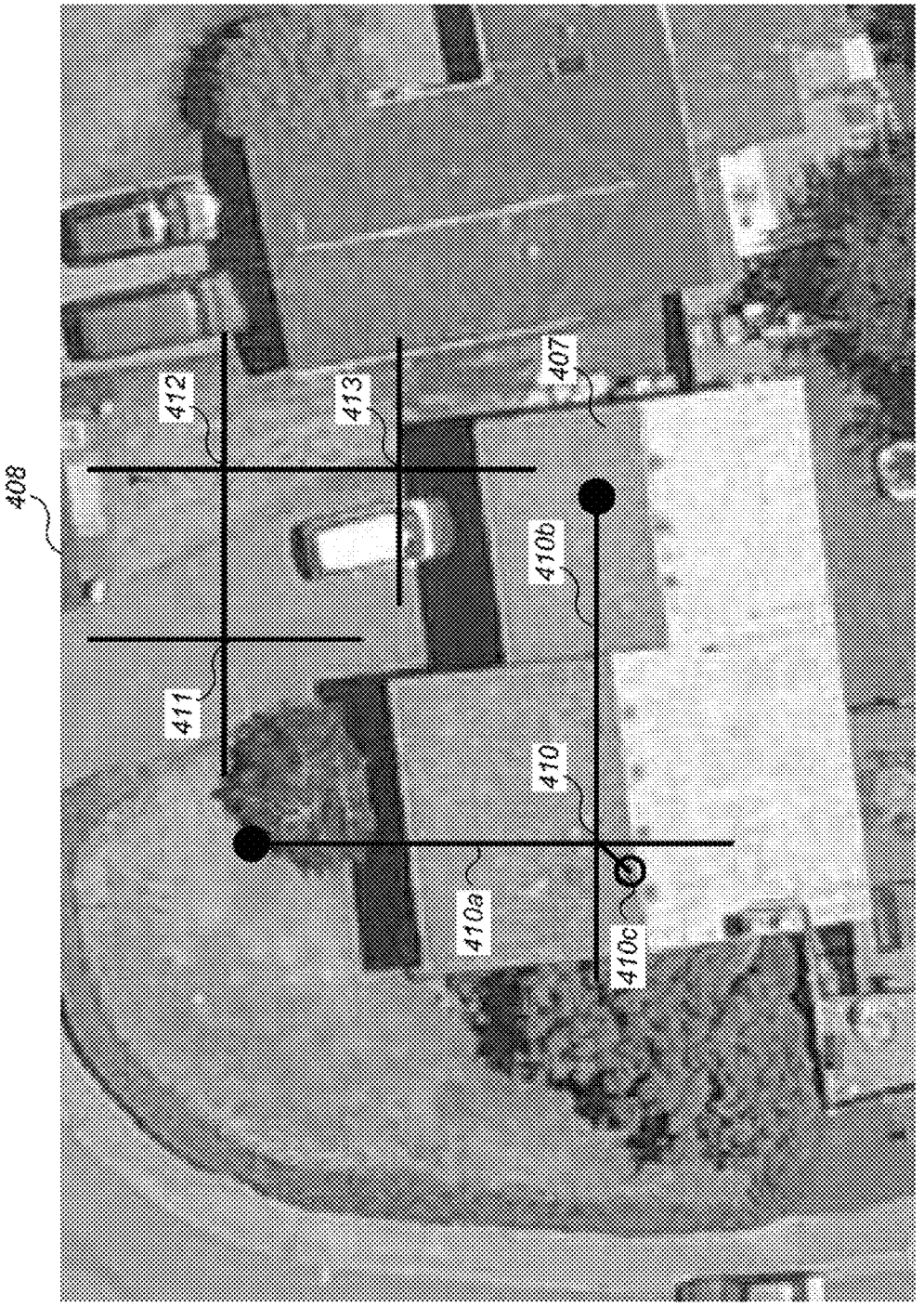

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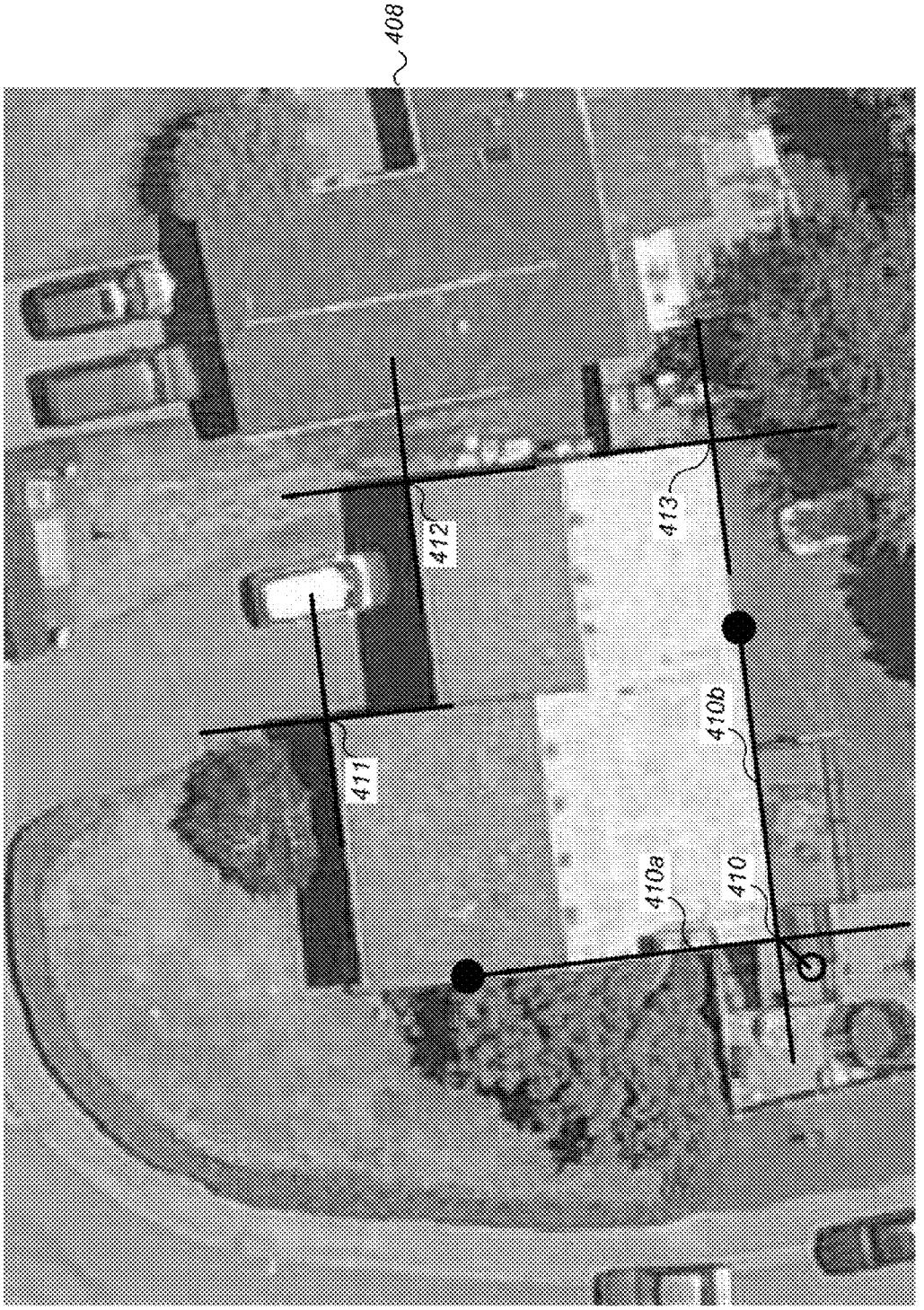

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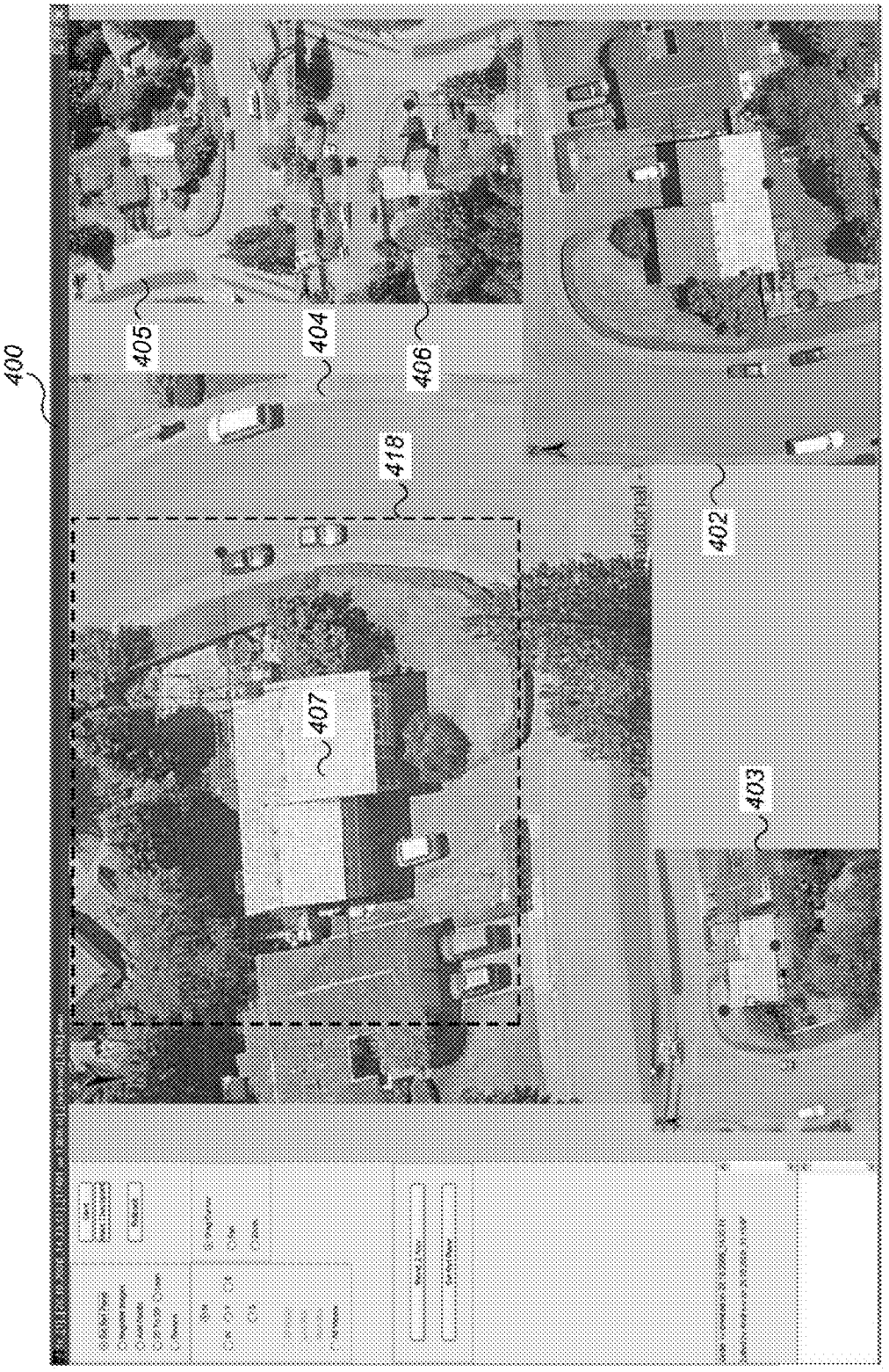

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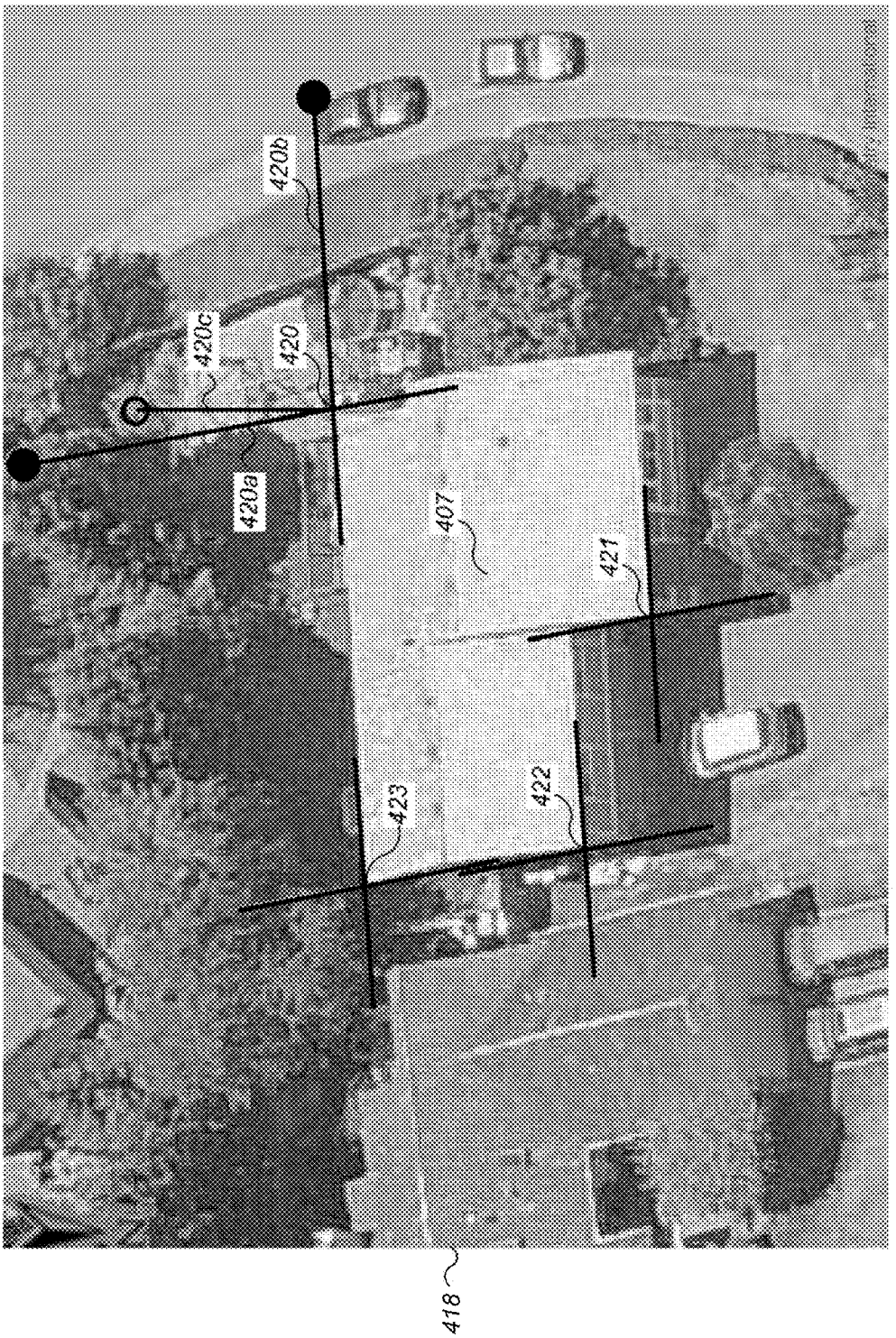

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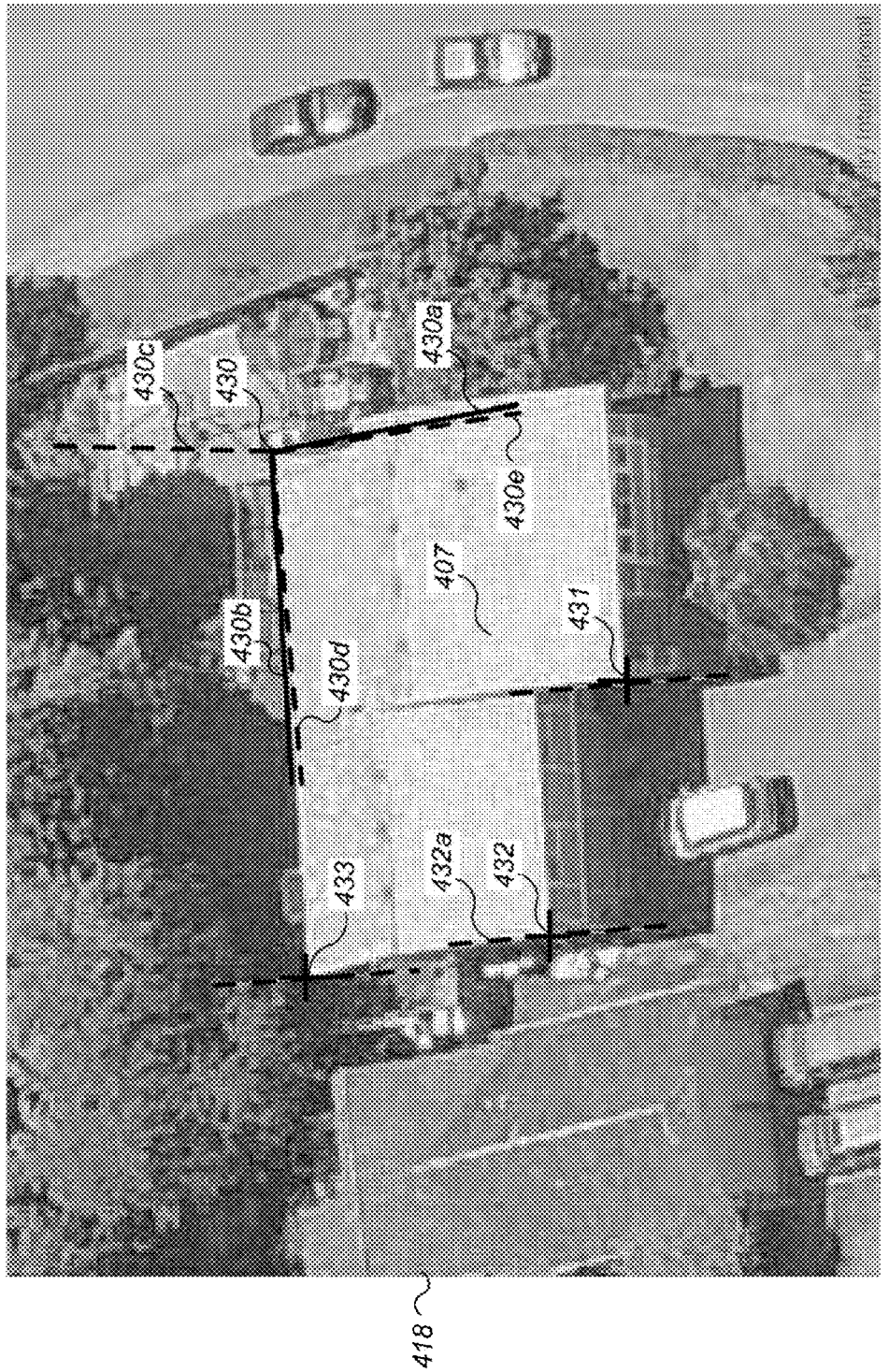

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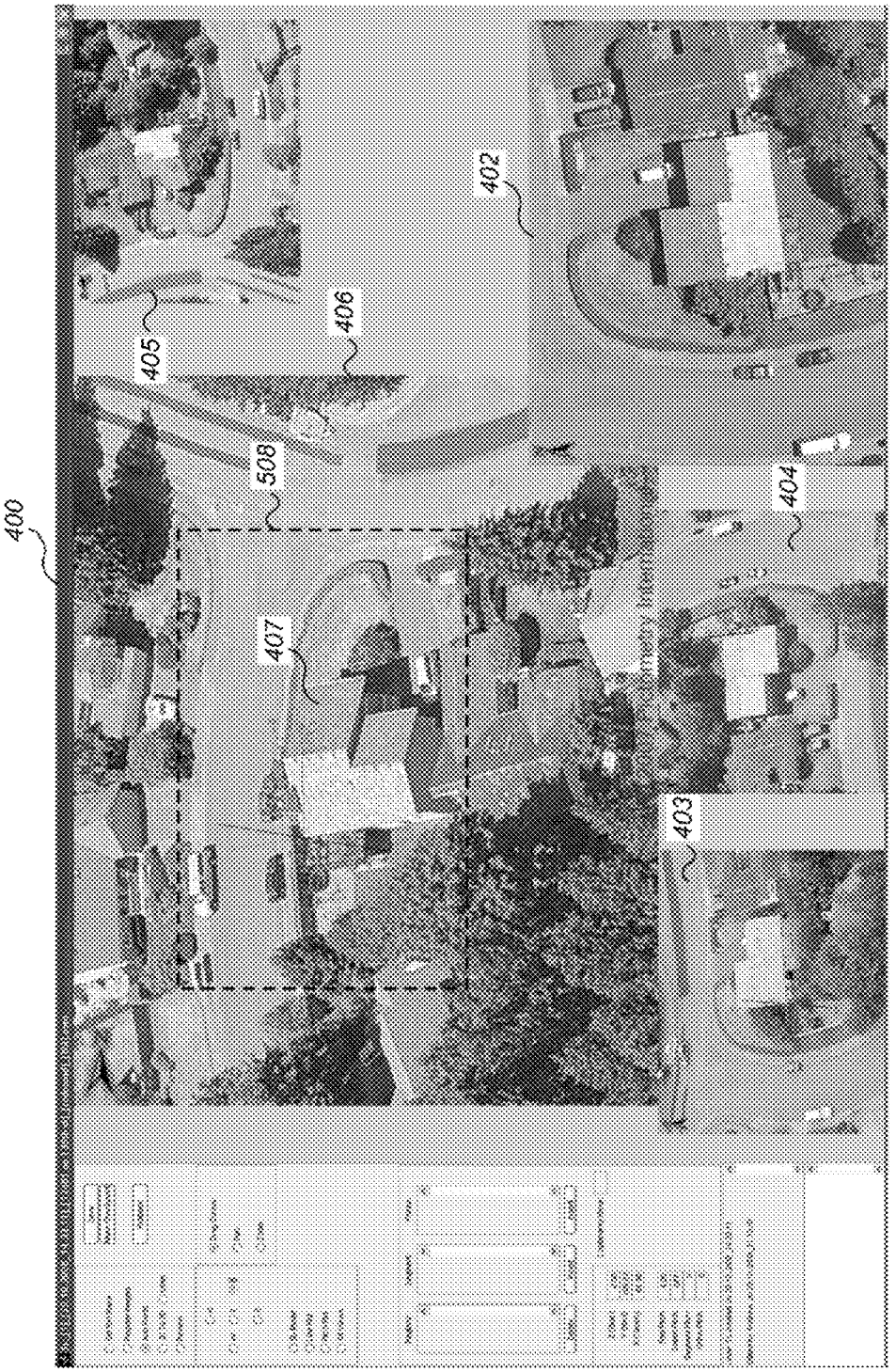

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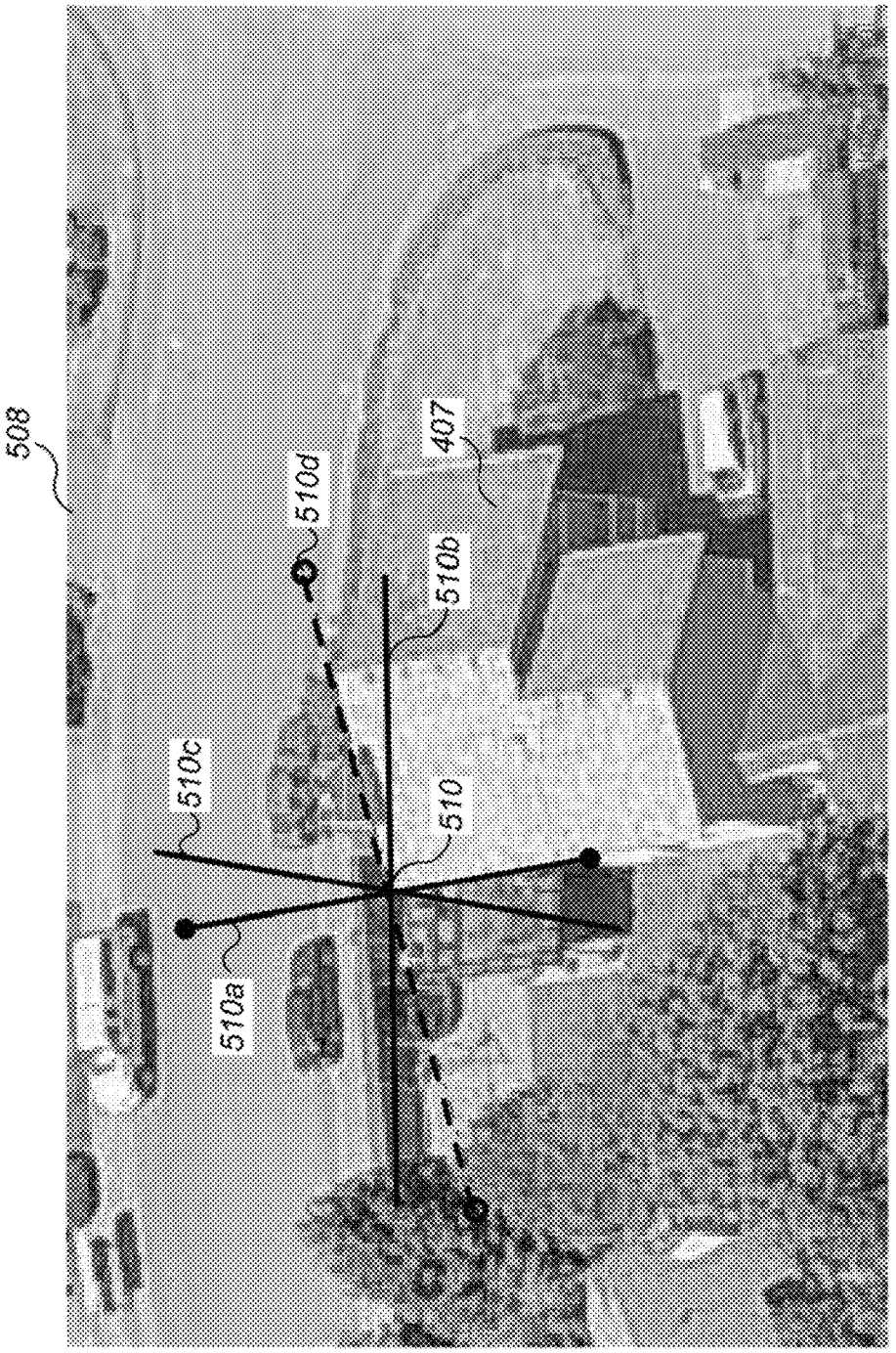

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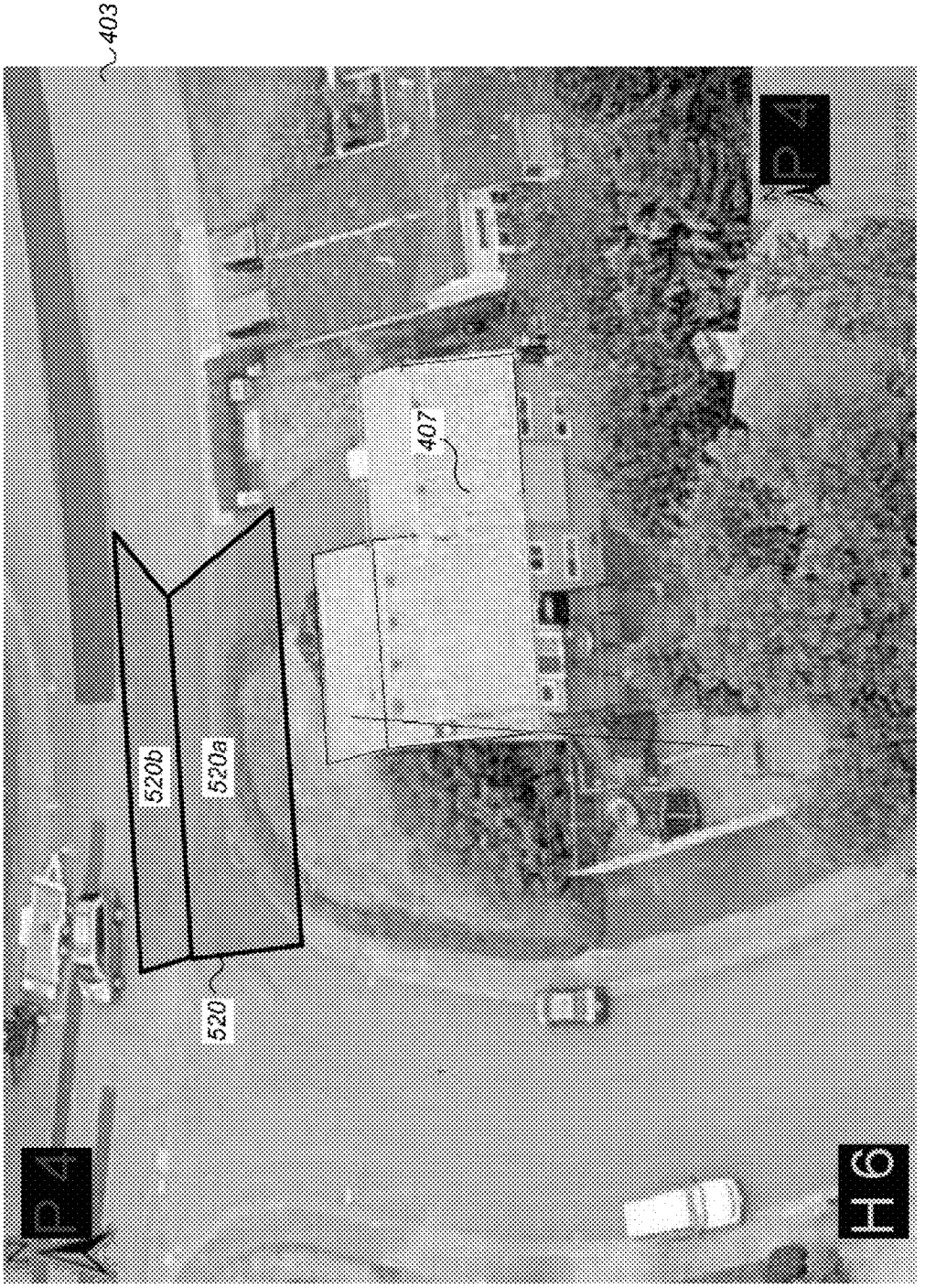

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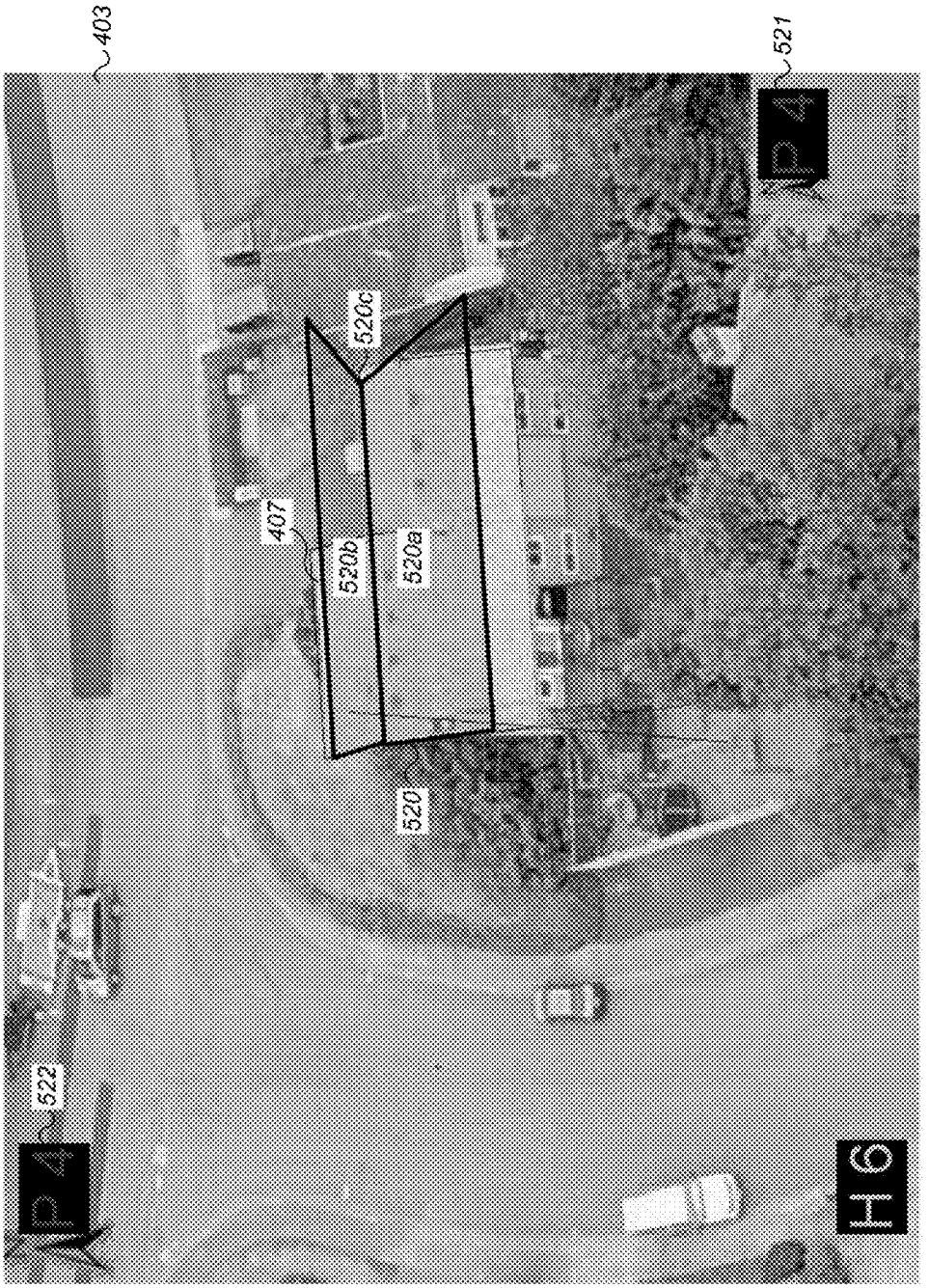

Fig. 5D

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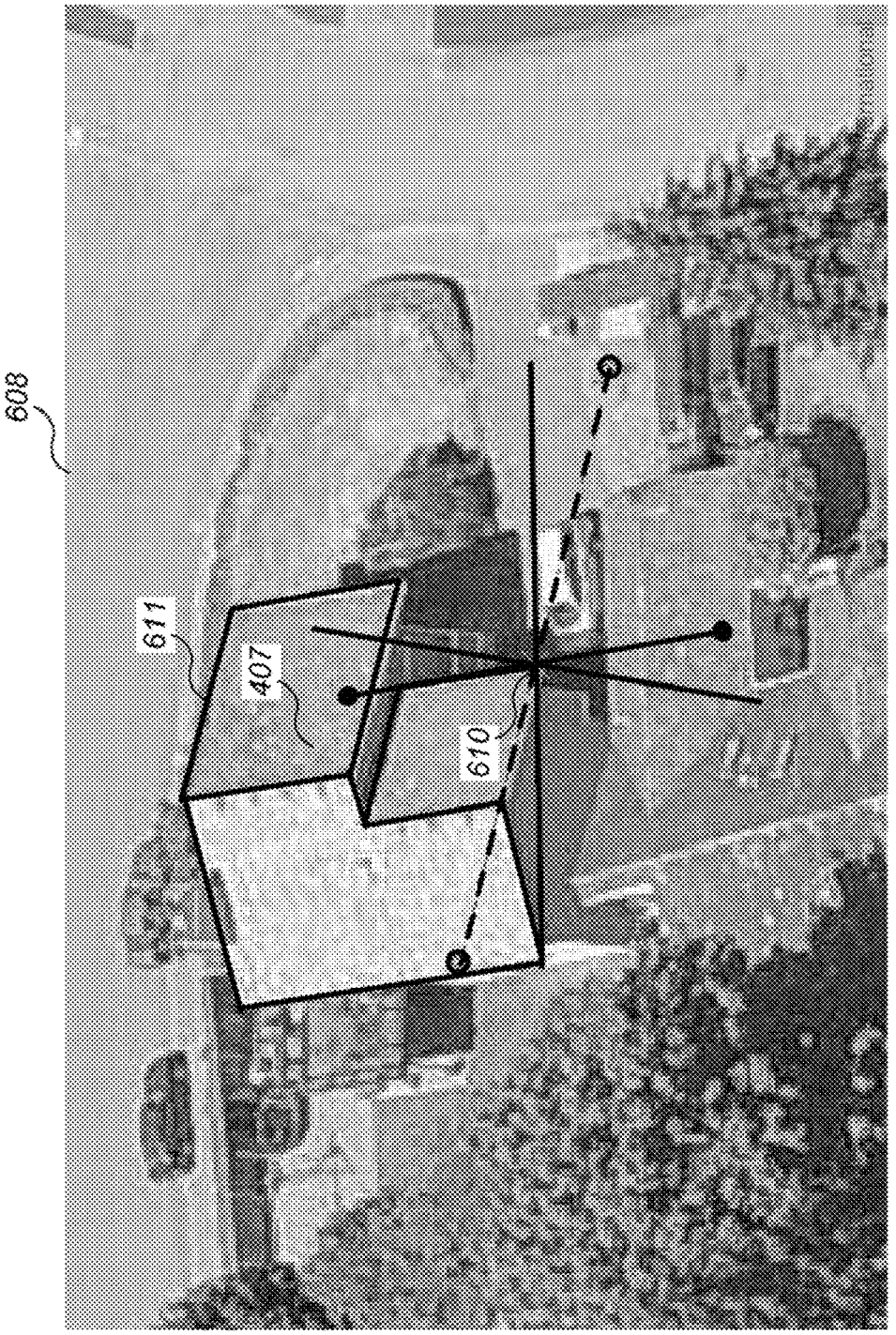

Fig. 6B

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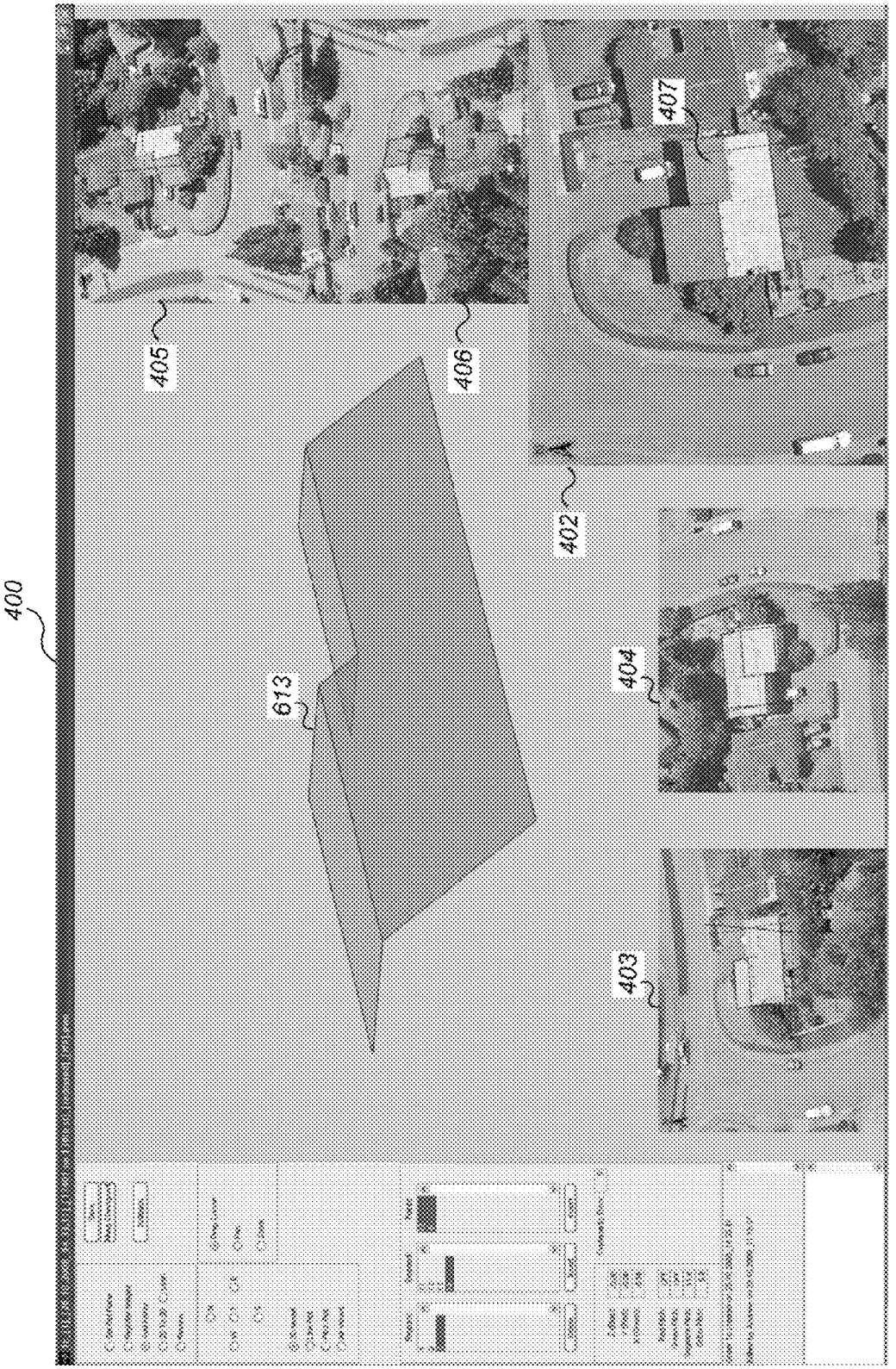

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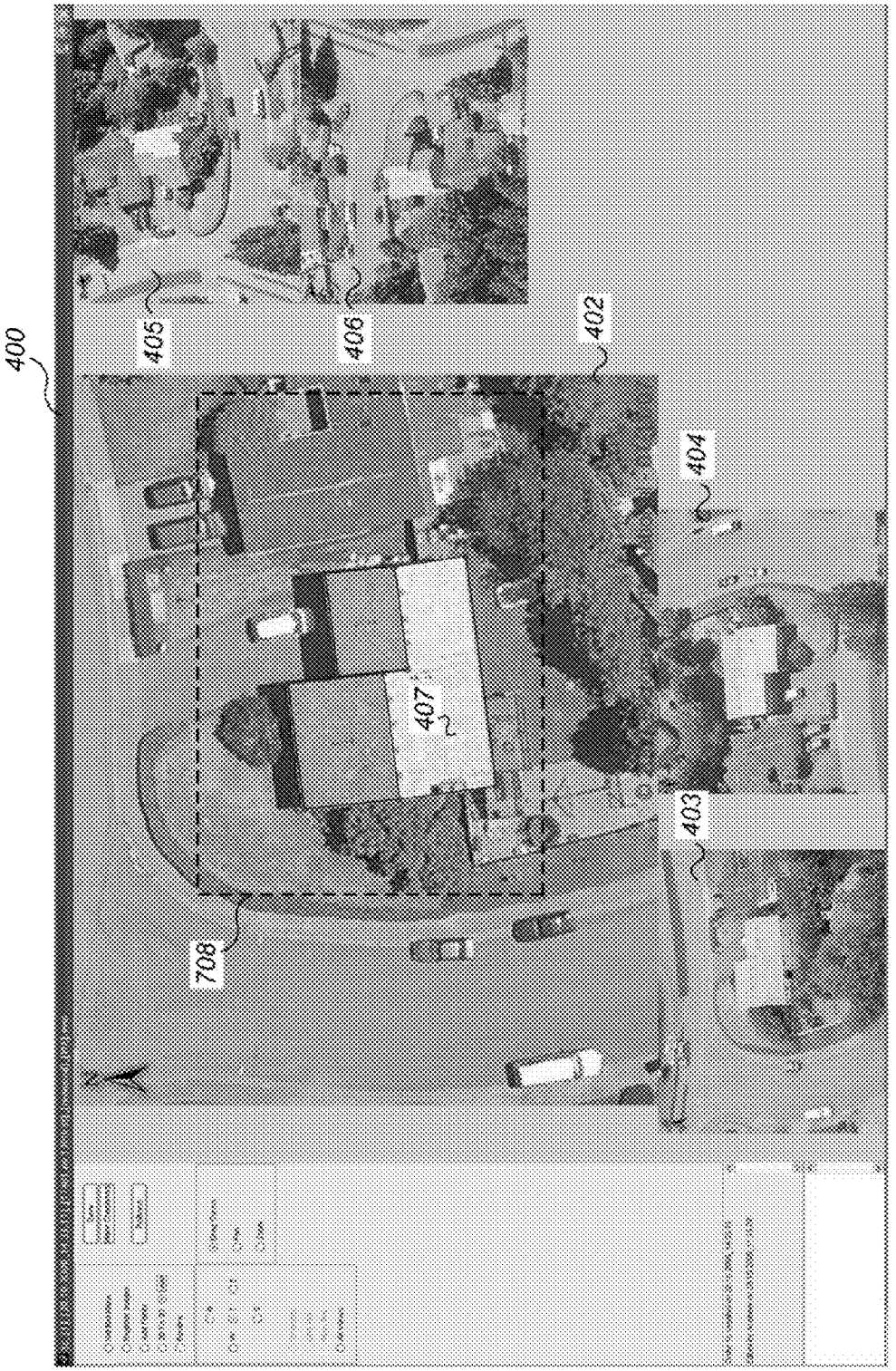

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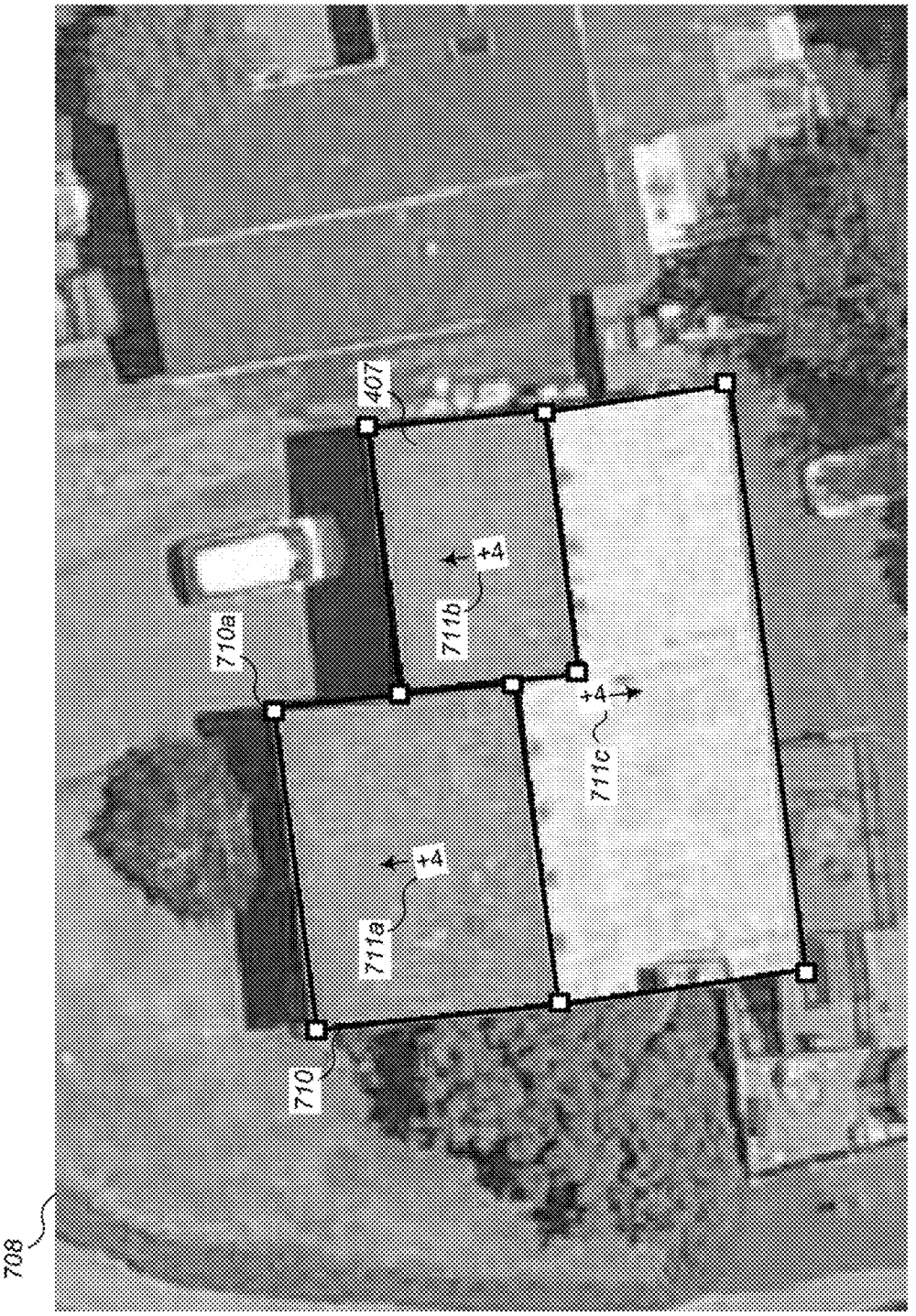

Fig. 7B

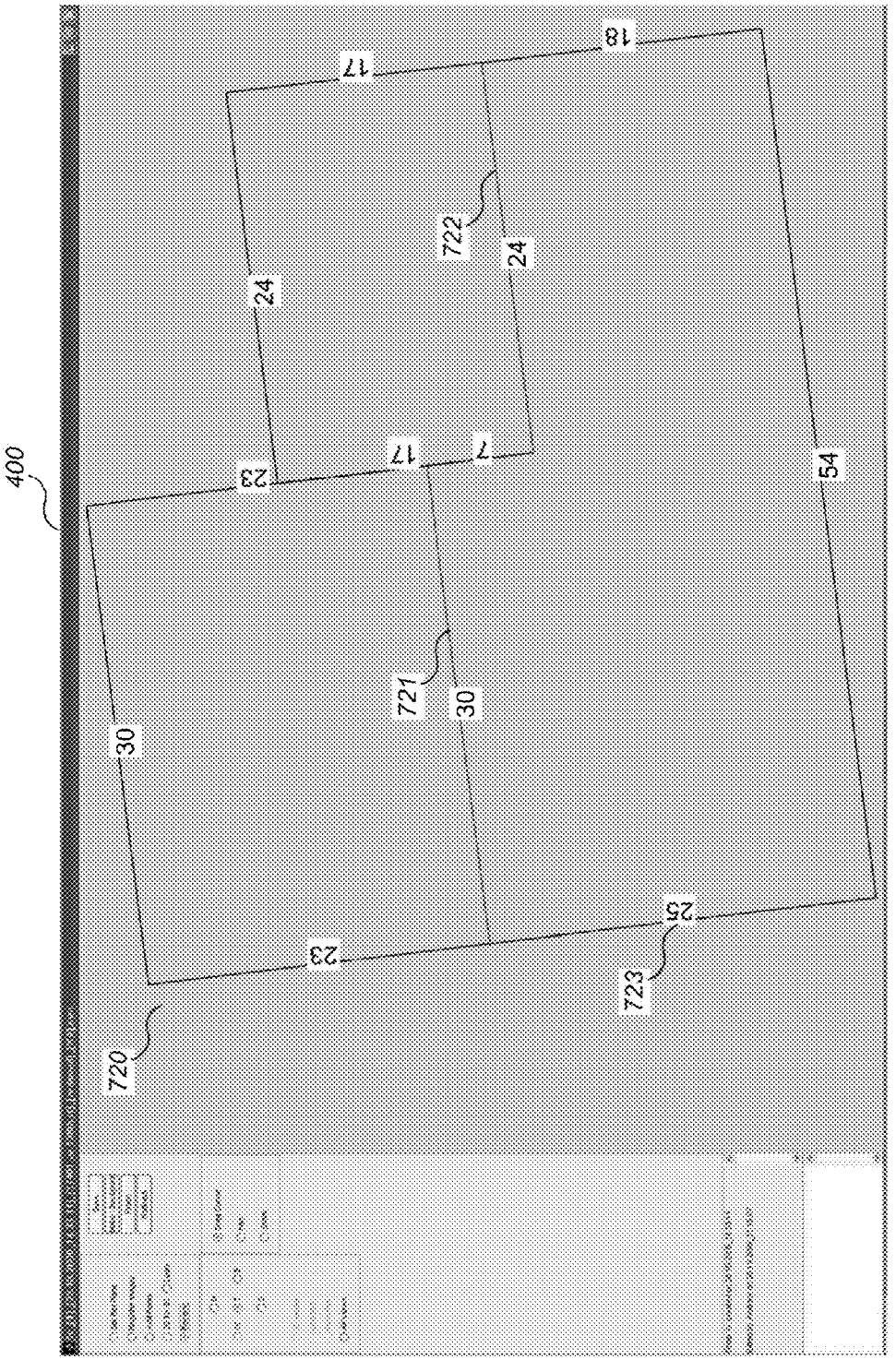

Fig. 7C

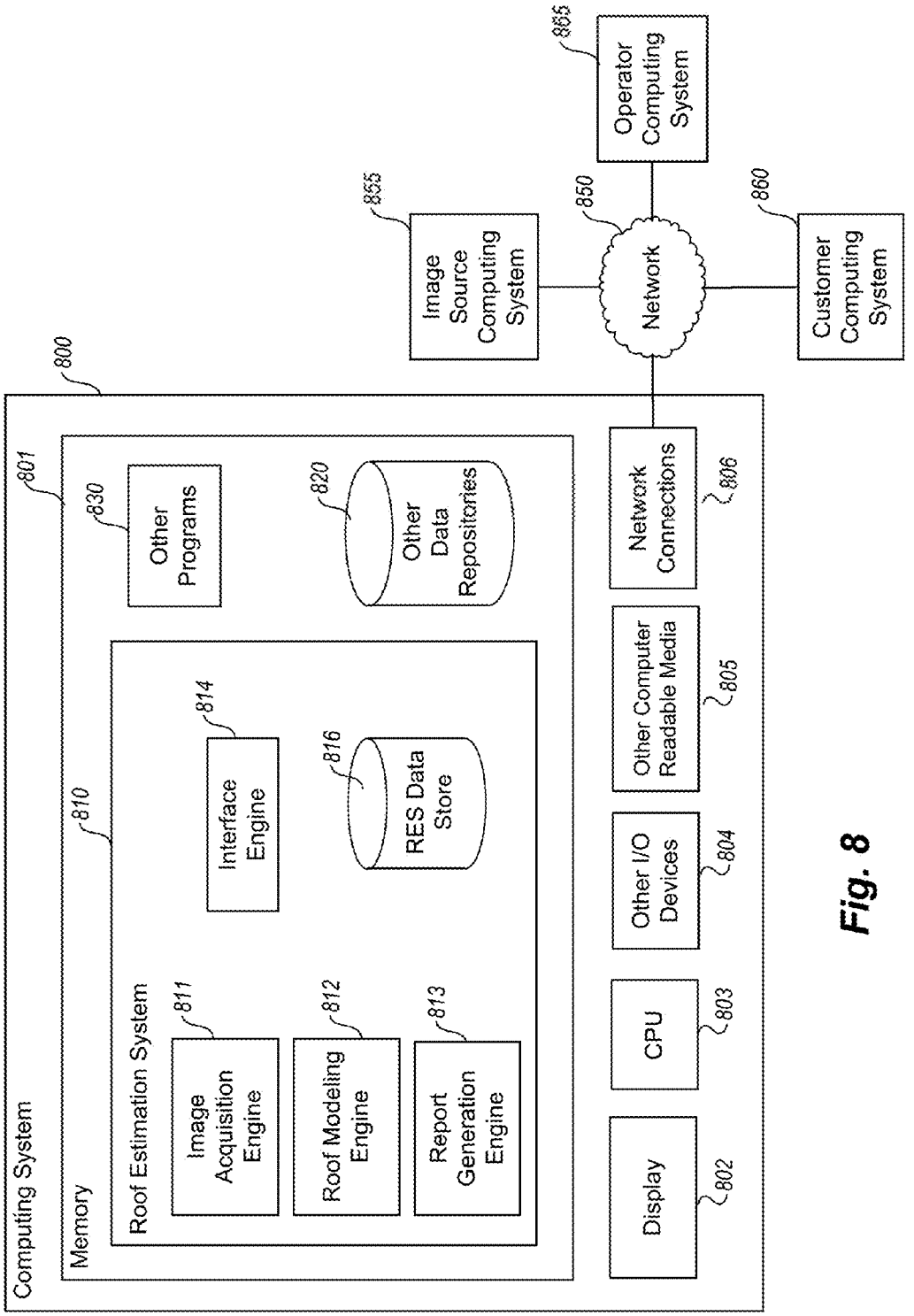
Computing System
800
Memory
801
Roof Estimation System
810
Image Acquisition Engine
811
Roof Modeling Engine
812
Report Generation Engine
813
Interface Engine
814
RES Data Store
816
Other Data Repositories
820
Other Programs
830
Display
802
CPU
803
Other I/O Devices
804
Other Computer Readable Media
805
Network Connections
806
Image Source Computing System
855
Network
850
Operator Computing System
865
Customer Computing System
860

Fig. 8

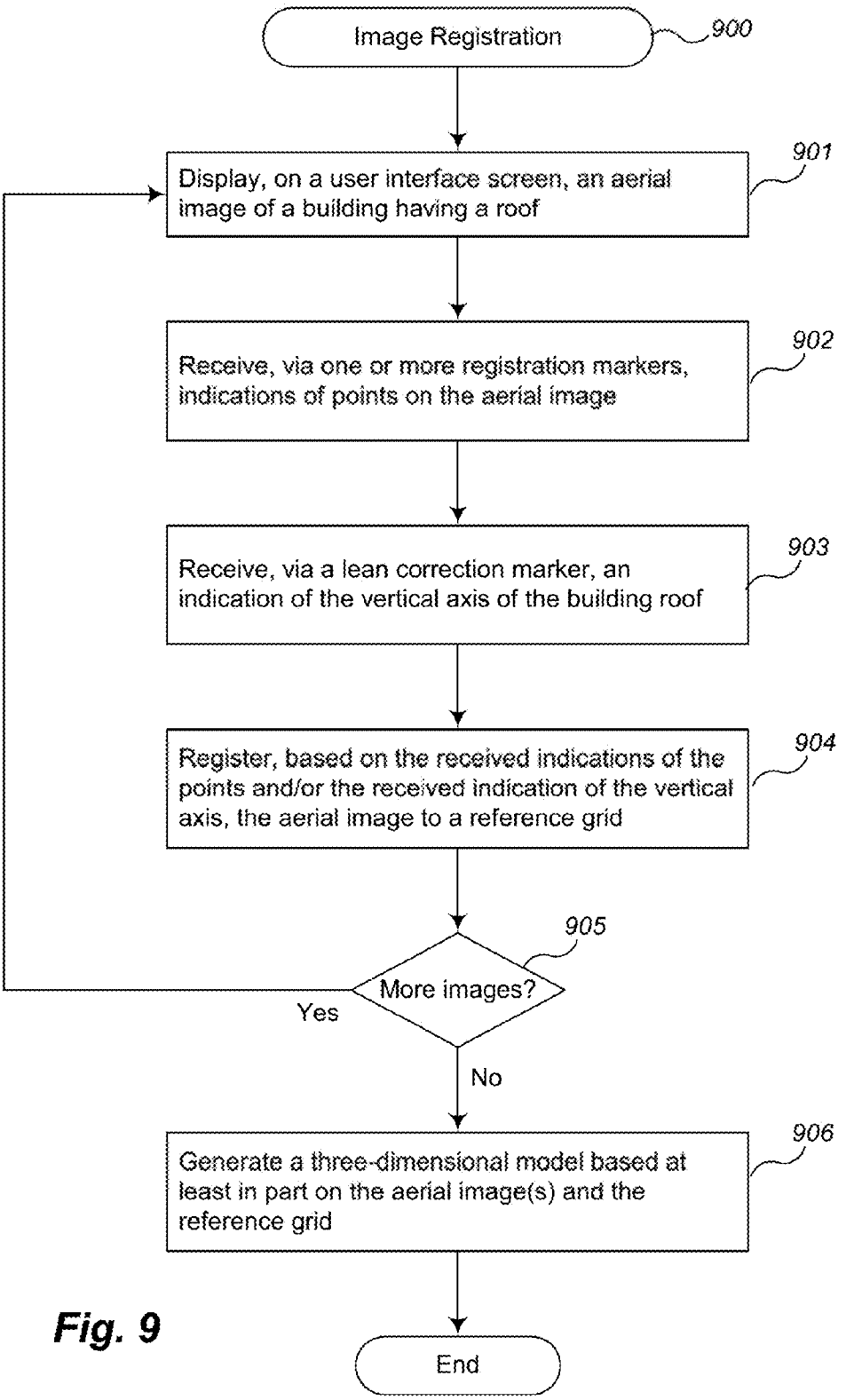
Image Registration
900
Display, on a user interface screen, an aerial image of a building having a roof
901
Receive, via one or more registration markers, indications of points on the aerial image
902
Receive, via a lean correction marker, an indication of the vertical axis of the building roof
903
Register, based on the received indications of the points and/or the received indication of the vertical axis, the aerial image to a reference grid
904
More images?
905
Yes
No
Generate a three-dimensional model based at least in part on the aerial image(s) and the reference grid
906
End

Fig. 9

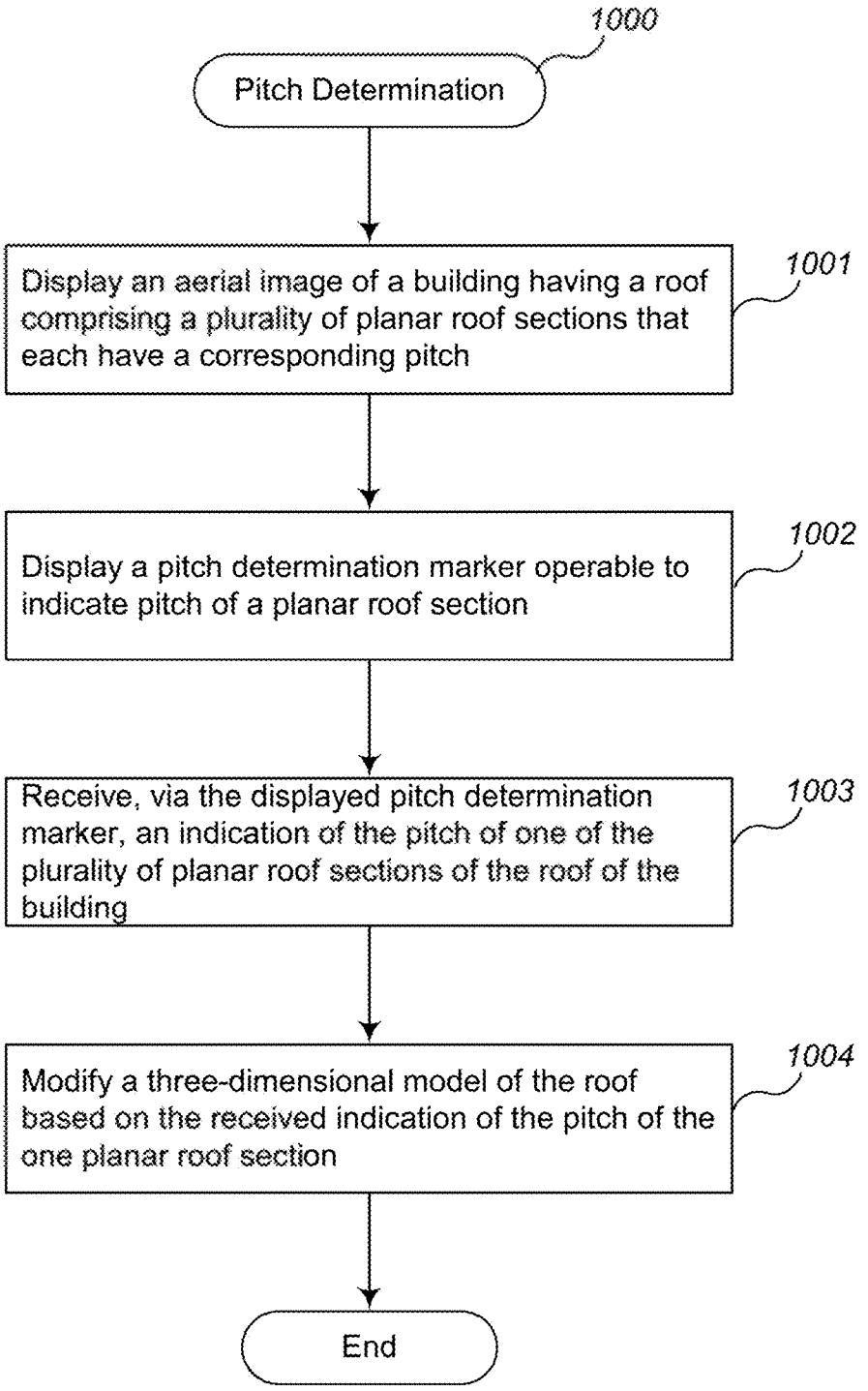
1000
Pitch Determination
Display an aerial image of a building having a roof comprising a plurality of planar roof sections that each have a corresponding pitch
1001
Display a pitch determination marker operable to indicate pitch of a planar roof section
1002
Receive, via the displayed pitch determination marker, an indication of the pitch of one of the plurality of planar roof sections of the roof of the building
1003
Modify a three-dimensional model of the roof based on the received indication of the pitch of the one planar roof section
1004
End

Fig. 10

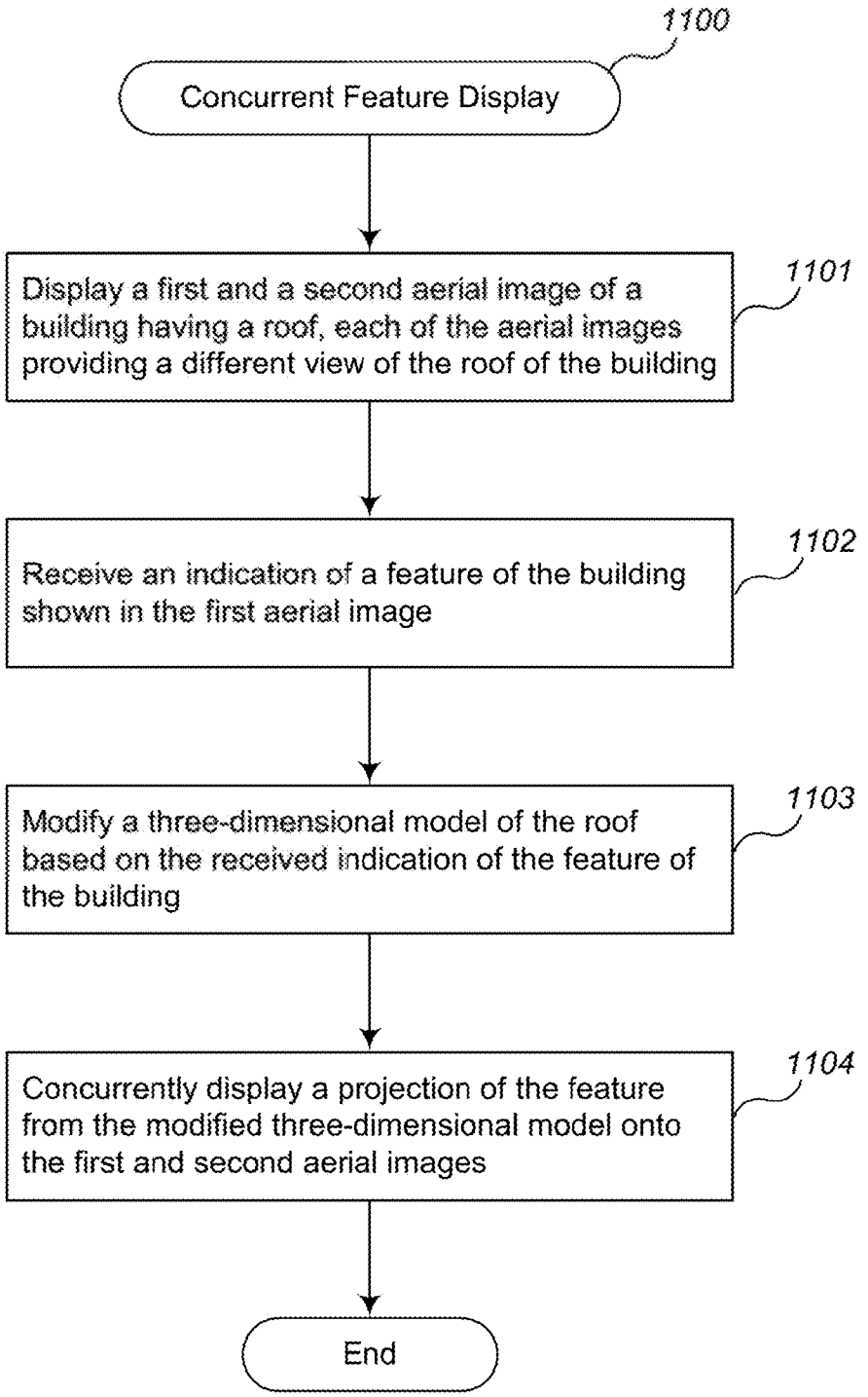
1100
Concurrent Feature Display
Display a first and a second aerial image of a building having a roof, each of the aerial images providing a different view of the roof of the building
1101
Receive an indication of a feature of the building shown in the first aerial image
1102
Modify a three-dimensional model of the roof based on the received indication of the feature of the building
1103
Concurrently display a projection of the feature from the modified three-dimensional model onto the first and second aerial images
1104
End

Fig. 11

CONCURRENT DISPLAY SYSTEMS AND METHODS FOR AERIAL ROOF ESTIMATION

BACKGROUND

1. Field of the Invention

This invention relates to systems and methods for estimating construction projects, and more particularly, to such systems and methods for determining roof measurement information based on one or more aerial images of a roof of a building.

2. Description of the Related Art

The information provided below is not admitted to be part of the present invention, but is provided solely to assist the understanding of the reader.

Homeowners typically ask several roofing contractors to provide written estimates to repair or replace a roof on a house. Heretofore, the homeowners would make an appointment with each roofing contractor to visit the house to determine the style of roof, take measurements, and to inspect the area around the house for access and cleanup. Using this information, the roofing contractor then prepares a written estimate and then timely delivers it to the homeowner. After receiving several estimates from different roofing contractors, the homeowner then selects one.

There are factors that impact a roofing contractor's ability to provide a timely written estimate. One factor is the size of the roof contractor's company and the location of the roofing jobs currently underway. Most roof contractors provide roofing services and estimates to building owners over a large geographical area. Larger roof contractor companies hire one or more trained individuals who travel throughout the entire area providing written estimates. With smaller roofing contractors, the owner or a key trained person is appointed to provide estimates. With both types of companies, roofing estimates are normally scheduled for buildings located in the same area on a particular day. If an estimate is needed suddenly at a distant location, the time for travel and the cost of commuting can be prohibitive. If the roofing contractor is a small company, the removal of the owner or key person on a current job site can be time prohibitive.

Another factor that may impact the roofing contractor's ability to provide a written estimate is weather and traffic.

Recently, solar panels have become popular. In order to install solar panels, the roof's slope, geometrical shape, and size as well as its orientation with respect to the sun all must be determined in order to provide an estimate of the number and type of solar panels required. Unfortunately, not all roofs on a building are proper size, geometrical shape, or orientation for use with solar panels.

SUMMARY

These and other objects are met by the systems and methods disclosed herein that determine and provide roof measurement information about the sizes, dimensions, slopes and orientations of the roof sections of a building roof. Roof measurement information may be used to generate a roof estimate report that provides and graphically shows this information. A roof estimation system that practices at least some of the techniques described herein may include an image acquisition engine, a roof modeling engine, and a report generation engine. The roof estimation system is configured to generate a model of a roof of a building, based on one or more aerial images. In addition, the roof estimation system is configured to determine roof measurement information and generate a roof estimate report based on the generated model and/or the determined roof measurement information.

In some embodiments, the roof estimation system includes a user interface engine which provides access to at least some of the functions of the roof estimation system. In one embodiment, the user interface engine provides interactive user interface components operable by an operator to perform various functions related to generating a model of a roof of a building, including image registration, lean correction, pitch determination, feature identification, and model review and/or correction.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating example functional elements of one embodiment of a roof estimation system.

FIGS. **2**A-**2**B illustrate aerial images of a building at a particular address.

FIGS. **3**A-**3**F illustrate individual pages of an example roof estimate report generated by an example embodiment of a roof estimation system.

FIGS. **4**A-**4**F are screen displays illustrating image registration and image lean correction in an example embodiment. (Also shows lean correction.)

FIGS. **5**A-**5**D are screen displays illustrating pitch determination in an example embodiment.

FIGS. **6**A-**6**D are screen displays illustrating model construction and concurrent display of operator specified roof features in an example embodiment.

FIGS. **7**A-**7**C are screen displays illustrating roof model review in an example embodiment.

FIG. **8** is an example block diagram of a computing system for practicing embodiments of a roof estimation system.

FIG. **9** is an example flow diagram of an image registration routine provided by an example embodiment.

FIG. **10** is an example flow diagram of a pitch determination routine provided by an example embodiment.

FIG. **11** is an example flow diagram of concurrent feature display routine provided by an example embodiment.

DETAILED DESCRIPTION

Embodiments described herein provide enhanced computer- and network-based methods, techniques, and systems for estimating construction projects based on one or more images of a structure. Example embodiments provide a Roof Estimation System ("RES") that is operable to provide a roof estimate report for a specified building, based on one or more aerial images of the building. In one embodiment, a customer of the RES specifies the building by providing an address of the building. The RES then obtains one or more aerial images showing at least portions of the roof of the building. Next, the RES generates a model of the roof of the building, which is then utilized to determine roof measurement information. The roof measurement information may include measurements such as lengths of the edges of sections of the roof, pitches of sections of the roof, areas of sections of the roof, etc. The model of the roof and/or the roof measurement information is then used to generate a roof estimate report. The roof estimate report includes one or more line drawings of the roof of the building, which are annotated with information about the roof, such as lengths of the edges of sections of the roof, pitches of sections of the roof, areas of sections of the roof, etc.

Some embodiments of the roof estimation system include an interactive user interface configured to provide access to one or more of the functions of the roof estimation system. In

one embodiment, the roof estimation system includes user interface controls that facilitate image registration, image lean correction, roof model generation, pitch determination, and roof model review. Image registration includes aligning, based at least in part on operator inputs, one or more images of a building roof to a set of reference points within a single three-dimensional ("3D") grid that is shared between the one or more images. Roof model generation includes generating a 3D model of a roof, based at least in part on operator inputs specifying various features and/or dimensional attributes of the roof. Roof model generation may further include the determination of the pitches of various planar sections of a roof. Roof model review includes display of a model of a roof, possibly in conjunction with one or more images of the roof, so that an operator may review the model for accuracy and possibly make adjustments and/or corrections to the roof model. In other embodiments, all or some of the functions of the roof estimation system may be performed automatically. For example, image registration may include automatically identifying building features for the placement of reference markers. Further, roof model generation may include automatically recognizing features, dimensional attributes, and/or pitches of various planar roof sections of the roof.

The described user interface is also configured to concurrently display roof features onto multiple images of a roof. For example, in the context of roof model generation, an operator may indicate a roof feature, such as an edge or a corner of a section of the roof, in a first image of the roof. As the roof estimation system receives the indication of the roof feature, the user interface concurrently displays that feature in one or more other images of the roof, so that the operator may obtain feedback regarding the accuracy of the roof model, the image registration, etc.

In the following, FIGS. **1-3** provide an overview of the operation of an example roof estimation system. FIGS. **4-7** provide additional details related to an example interactive user interface provided by one embodiment of the roof estimation system. FIGS. **8-11** provide details related to roof estimation system implementation techniques.

1. Roof Estimation System Overview

FIG. **1** is a block diagram illustrating example functional elements of one embodiment of a roof estimation system. In particular, FIG. **1** shows an example Roof Estimation System ("RES") **100** comprising an image acquisition engine **101**, a roof modeling engine **102**, a report generation engine **103**, image data **105**, model data **106**, and report data **107**. The RES **100** is communicatively coupled to an image source **110**, a customer **115**, and optionally an operator **120**. The RES **100** and its components may be implemented as part of a computing system, as will be further described with reference to FIG. **8**.

More specifically, in the illustrated embodiment of FIG. **1**, the RES **100** is configured to generate a roof estimate report **132** for a specified building, based on aerial images **131** of the building received from the image source **110**. The image source **110** may be any provider of images of the building for which a roof estimate is being generated. In one embodiment, the image source **110** includes a computing system that provides access to a repository of aerial images of one or more buildings. In addition, the aerial images **131** may include images obtained via manned or unmanned aircraft (e.g., airplane, helicopter, blimp, drone, etc.), satellite, etc. Furthermore, the aerial images **131** may include images obtained via one or more ground-based platforms, such as a vehicle-mounted camera that obtains street-level images of buildings, a nearby building, a hilltop, etc. In some cases, a vehicle-mounted camera may be mounted in an elevated position, such as a boom. Example aerial images are described further with reference to FIGS. **2A-2B**

The image acquisition engine **101** obtains one or more aerial images of the specified building by, for example, providing an indicator of the location of the specified building (e.g., street address, GPS coordinates, lot number, etc.) to the image source **110**. In response, the image source **110** provides to the image acquisition engine **101** the one or more aerial images of the building. The image acquisition engine **101** then stores the received aerial images as image data **105**, for further processing by other components of the RES **100**. Obtaining aerial images of a specified building may include various forms of geo-coding, performed by the image acquisition engine **101** and/or the image source **110**. In one embodiment, the image source geo-codes a provided street address into latitude and longitude coordinates, which are then used to look up (e.g., query a database) aerial images of the provided street address.

Next, the roof modeling engine **102** generates a model of the roof of the specified building. In the illustrated embodiment, the roof modeling engine **102** generates a three-dimensional ("3D") model, although in other embodiments, a two-dimensional (e.g., top-down roof plan) may be generated instead or in addition. Generating a model of the roof may generally include image calibration, in which the distance between two pixels on a given image is converted into a physical length. Image calibration may be performed automatically, such as based on meta-information provided along with the aerial images **131**.

A variety of automatic and semi-automatic techniques may be employed to generate a model of the roof of the building. In one embodiment, generating such a model is based at least in part on a correlation between at least two of the aerial images of the building. For example, the roof modeling engine **102** receives an indication of a corresponding feature that is shown in each of the two aerial images. In one embodiment, an operator **120**, viewing two or more images of the building, inputs an indication in at least some of the images, the indications identifying which points of the images correspond to each other for model generation purposes.

The corresponding feature may be, for example, a vertex of the roof of the building, the corner of one of the roof planes of the roof, a point of a gable or hip of the roof, etc. The corresponding feature may also be a linear feature, such as a ridge or valley line between two roof planes of the roof. In one embodiment, the indication of a corresponding feature on the building includes "registration" of a first point in a first aerial image, and a second point in a second aerial image, the first and second points corresponding to substantially the same point on the roof of the building. Generally, point registration may include the identification of any feature shown in both aerial images. Thus, the feature need not be a point on the roof of the building. Instead, it may be, for example, any point that is visible on both aerial images, such as on a nearby building (e.g., a garage, neighbor's building, etc.), on a nearby structure (e.g., swimming pool, tennis court, etc.), on a nearby natural feature (e.g., a tree, boulder, etc.), etc.

In some embodiments, the roof modeling engine **102** determines the corresponding feature automatically, such as by employing on one or more image processing techniques used to identify vertexes, edges, or other features of the roof. In other embodiments, the roof modeling engine **102** determines the corresponding feature by receiving, from the human operator **120** as operator input **133**, indications of the feature shown in multiple images of the building.

In one example embodiment, the RES **100** generates a model of the roof of the building in the following manner.

First, a set of reference points are be identified in each of the images. These reference points are identified by the operator **120** utilizing a suitable input device, such as a mouse or joystick. The roof modeling engine **102** then uses these reference points and any acceptable algorithm to co-register the images and reconstruct the three-dimensional geometry of the object identified by the reference points. There are a variety of photogrammetric algorithms that can be utilized to perform this reconstruction. One such algorithm used by the RES **100** uses photographs taken from two or more view points to "triangulate" points of interest on the object in three-dimensional ("3D") space. This triangulation can be visualized as a process of projecting a line originating from the location of the photograph's observation point that passes through a particular reference point in the image. The intersection of these projected lines from the set of observation points to a particular reference point identifies the location of that point in 3D space. Repeating the process for all such reference points allows the software to determine a 3D volume suitable for building a 3D model of the structure. The choice of reconstruction algorithm depends on a number of factors such as the spatial relationships between the photographs, the number and locations of the reference points, and any assumptions that are made about the geometry and symmetry of the object being reconstructed. Several such algorithms are described in detail in textbooks, trade journals, and academic publications.

In addition, generating a model of the roof of a building may include correcting one or more of the aerial images for various imperfections. For example, the vertical axis of a particular aerial image sometimes will not substantially match the actual vertical axis of its scene. This will happen, for example, if the aerial images were taken at different distances from the building, or at a different pitch, roll, or yaw angles of the aircraft from which the images were produced. In such cases, an aerial image may be corrected by providing the operator **120** with a user interface control operable to adjust the scale and/or relative angle of the aerial image to correct for such errors. The correction may be either applied directly to the aerial image, or instead be stored (e.g., as an offset) for use in model generation or other functions of the RES **100**.

Generating a model of the roof of a building further includes the automatic or semi-automatic identification of features of the roof of the building. In one embodiment, one or more user interface controls may be provided, such that the operator **120** may indicate (e.g., draw, paint, etc.) various features of the roof, such as valleys, ridges, hips, vertexes, planes, edges, etc. As these features are indicated by the operator **120**, a corresponding three-dimensional ("3D") model may be updated accordingly to include those features. These features are identified by the operator based on a visual inspection of the images and by providing inputs that identify various features as valleys, ridges, hips, etc. In some cases, a first and a second image view of the roof (e.g., a north and east view) are simultaneously presented to the operator **120**, such that when the operator **120** indicates a feature in the first image view, a projection of that feature is automatically presented in the second image view. By presenting a view of the 3D model, simultaneously projected into multiple image views, the operator **120** is provided with useful visual cues as to the correctness of the 3D model and/or the correspondence between the aerial images.

In addition, generating a model of the roof of a building may include determining the pitch of one or more of the sections of the roof. In some embodiments, one or more user interface controls are provided, such that the operator **120** may accurately determine the pitch of each of the one or more roof sections. An accurate determination of the roof pitch may be employed (by a human or the RES **100**) to better determine an accurate cost estimate, as roof sections having a low pitch are typically less costly surfaces to repair and/or replace.

The generated model typically includes a plurality of planar roof sections that each correspond to one of the planar sections of the roof of the building. Each of the planar roof sections in the model has a number of associated dimensions and/or attributes, among them slope, area, and length of each edge of the roof section. Other information may include any information relevant to a roof builder or other entity having an interest in construction of, or installation upon, the roof. For example, the other information may include identification of valleys, ridges, rakes, eaves, or hip ridges of the roof and/or its sections; roof and/or roof section perimeter dimensions and/or outlines; measurements of step heights between different roof levels (e.g., terraces); bearing and/or orientation of each roof section; light exposure and/or shadowing patterns due to chimneys, other structures, trees, latitude, etc.; roofing material; etc. Once a 3D model has been generated to the satisfaction of the roof modeling engine **102** and/or the operator **120**, the generated 3D model is stored as model data **106** for further processing by the RES **100**. In one embodiment, the generated 3D model is then stored in a quality assurance queue, from which it is reviewed and possibly corrected by a quality control operator.

The report generation engine **103** generates a final roof estimate report based on a model stored as model data **106**, and then stores the generated report as report data **107**. Such a report typically includes one or more plan (top-down) views of the model, annotated with numerical values for the slope, area, and/or lengths of the edges of at least some of the plurality of planar roof sections of the model of the roof. The report may also include information about total area of the roof, identification and measurement of ridges and/or valleys of the roof, and/or different elevation views rendered from the 3D model (top, side, front, etc). An example report is illustrated and discussed with respect to FIGS. **3**A-**3**E, below.

In some embodiments, generating a report includes labeling one or more views of the model with annotations that are readable to a human user. Some models include a large number of small roof details, such as dormers or other sections, such that applying uniformly sized, oriented, and positioned labels to roof section views results in a visually cluttered diagram. Accordingly, various techniques may be employed to generate a readable report, including automatically determining an optimal or near-optimal label font size, label position, and/or label orientation, such that the resulting report may be easily read and understood by the customer **115**.

In addition, in some embodiments, generating a report includes automatically determining a cost estimate, based on specified costs, such as those of materials, labor, transportation, etc. For example, the customer **115** provides indications of material and labor costs to the RES **100**. In response, the report generation engine **103** generates a roof estimate report that includes a cost estimate, based on the costs provided by the customer **115** and the attributes of the particular roof, such as area, pitch, etc.

In one embodiment, the generated report is then provided to a customer. The generated report can be represented, for example, as an electronic file (e.g., a PDF file) or a paper document. In the illustrated example, roof estimate report **132** is transmitted to the customer **115**. The customer **115** may be or include any human, organization, or computing system that is the recipient of the roof estimate report **132**. For example, the customer **115** may be a property owner, a property man-

ager, a roof construction/repair company, a general contractor, an insurance company, a solar power panel installer, a climate control (e.g., heating, ventilation, and/or air conditioning) system installer, a roof gutter installer, an awning installer, etc. Reports may be transmitted electronically, such as via a network (e.g., as an email, Web page, etc.) or by some shipping mechanism, such as the postal service, a courier service, etc.

In some embodiments, one or more of the models stored as model data **106** are provided directly to the customer or other computing system, without first being transformed into a report. For example, a model and/or roof measurement information based thereon may be exported and/or transmitted as a data file, in any suitable format, that may be consumed or otherwise utilized by some other computing system, such as a computer-aided design ("CAD") tool, a drawing program, a labor and material estimation software, a project management/estimation software, etc.

The RES **100** may be operated by various types of entities. In one embodiment, the RES **100** is operated by a roof estimation service that provides roof estimate reports to customers, such as roofing contractors, in exchange for payment. In another embodiment, the RES **100** is operated by a roof construction/repair company, to generate roof estimate reports that are used internally and/or provided to customers, such as property owners.

In addition, the RES **100** may be operated in various ways. In one embodiment, the RES **100** executes as a desktop computer application that is operated by the operator **120**. In another embodiment, the RES **100** executes as a network-accessible service, such as by a Web server, that may be operated remotely by the operator **120** and/or the customer **115**. Additional details regarding the implementation of an example roof estimation system are provided with respect to FIG. **8**, below.

FIGS. **2**A-**2**B illustrate aerial images of a building at a particular address. In the illustrated example, the aerial images are represented as stylized line drawings for clarity of explanation. As noted above, such aerial images may be acquired in various ways. In one embodiment, an aircraft, such as an airplane or helicopter is utilized to take photographs while flying over one or more properties. Such aircraft may be manned or unmanned. In another embodiment, a ground-based vehicle, such as a car or truck, is utilized to take photographs (e.g., "street view" photographs) while driving past one or more properties. In such an embodiment, a camera may be mounted on a boom or other elevating member, such that images of building roofs may be obtained. In another embodiment, photographs may be taken from a fixed position, such as a tall building, hilltop, tower, etc.

In particular, FIG. **2**A shows a top plan (top-down) aerial image **210** of a building **200**. The roof of the building **200** includes multiple planar roof sections **200***a*-**200***d*. FIG. **2**A also shows a second aerial image **211** providing a perspective (oblique) view of the building **200**. The roof sections **200***a* and **200***c* are also visible in image **211**.

FIG. **2**B shows a top-down, wide angle image **212** of the building **200**. The image **212** includes details of the surrounding areas **220** of the building **220**. Information about the surrounding areas **220** of the building **220** are in some embodiments used to determine additional cost factors related to a roof estimate. For example, the cleanup of, or access to, a worksite at building **220** may be complicated by various factors, including a substantial amount of landscaping; steeply sloped building sites; proximity to environmentally sensitive areas; etc. In such cases, the roof estimation system may automatically increase a cost factor in a corresponding roof estimate report.

In some embodiments, an aerial image has corresponding meta-information. Such meta-information may include details about the type of camera used (e.g., focal length, exposure, etc.), the position of the camera (e.g., GPS coordinates of the aircraft at the time the image was captured), the orientation of the camera (e.g., the angle of the camera), the time and/or date the image was captured, etc.

FIGS. **3**A-**3**F illustrate individual pages of an example roof estimate report generated by an example embodiment of a roof estimation system. As discussed with respect to FIG. **1**, a roof estimate report is generated by the roof estimation system based on one or more aerial images of a building. The roof estimate report may be based on a computer model (e.g., a 3D model) of the roof, and includes one or more views of the model. In this example, the various views of the model are presented as annotated line drawings, which provide information about the roof, such as the roof section areas, roof section edge lengths, roof section pitches, etc. The roof estimate report may be in an electronic format (e.g., a PDF file) and/or paper format (e.g., a printed report). In some embodiments, the roof estimate report may be in a format that may be consumed by a computer-aided design program.

FIG. **3**A shows a cover page **301** of the report and includes the address **301***a* of a building **301***c* and an overhead aerial image **301***b* of the building **301***c*.

FIG. **3**B shows a second page **302** of the report and includes two wide perspective (oblique) views **302***a* and **302***b* of the building **301***c* at the address with the surrounding areas more clearly shown.

FIG. **3**C shows a third page **303** of the report and includes a line drawing **303***a* of the building roof showing ridge lines **303***b* and **303***c*, and a compass indicator **303***d*. In addition, a building roof having valleys would result in a line drawing including one or more valley lines. The ridge and/or valley lines may be called out in particular colors. For example, ridge lines **303***b* and **303***c* may be illustrated in red, while valley lines may be illustrated in blue. The line drawing **303***a* is also annotated with the dimensions of the planar sections of the building roof. In this case, the dimensions are the lengths of the edges of the planar roof sections.

FIG. **3**D shows a fourth page **304** of the report and includes a line drawing **304***a* of the building roof showing the pitch of each roof section along with a compass indicator. The pitch in this example is given in inches, and it represents the number of vertical inches that the labeled planar roof section drops over 12 inches of horizontal run. The slope can be easily calculated from such a representation using basic trigonometry. The use of a numerical value of inches of rise per foot of run is a well known measure of slope in the roofing industry. A roof builder typically uses this information to assist in the repair and/or construction of a roof. Of course, other measures and/or units of slope may be utilized as well, including percent grade, angle in degrees, etc.

FIG. **3**E shows a fifth page **305** of the report and includes a line drawing **305***a* of the building roof showing the square footage of each roof section along with the total square foot area value. Of course, other units of area may be used as well, such as square meters or the number of "squares" of roofing material required for covering each roof section.

FIG. **3**F shows a fifth page **306** of the report and includes a line drawing **306***a* of the building roof where notes or comments may be written. The line drawing **306***a* includes a label for each roof section (shown here as "A", "B", "C"), such that comments may be conveniently related to specific roof sections.

In other embodiments, more or less information may be provided, or the illustrated information may be arranged in different ways. For example, the report may be provided in electronic form, such as a PDF file or a computer aided design software format. In some embodiments, the report may be "active" or editable, such that the user of the report may make changes to the report, based on on-site observations.

2. Roof Estimation System User Interface

FIGS. **4**A-**4**F, **5**A-**5**D, **6**A-**6**D, and **7**A-**7**C describe an example interactive user interface provided by one embodiment of the roof estimation system. As noted, the RES **100** described with reference to FIG. **1** includes a user interface engine **104** that is configured to provide access to one or more functions of the RES **100**, including image registration (described with respect to FIGS. **4**A-**4**F), roof pitch determination (described with respect to FIGS. **5**A-**5**D), roof model construction (described with reference to FIGS. **6**A-**6**D), and roof model review (described with respect to FIGS. **7**A-**7**C).

A. Image Registration

FIGS. **4**A-**4**F are screen displays illustrating image registration and image lean correction in an example embodiment. In particular, FIG. **4**A shows a user interface screen **400** that is utilized by an operator to generate a three dimensional model of a roof of a building. The user interface screen **400** shows a roof modeling project in an initial state, after the operator has specified an address of a building and after images of the building have been obtained and loaded into the roof estimation system.

The user interface screen **400** includes a control panel **401** and five images **402**-**406** of a building roof **407**. The control panel **401** includes user selectable controls (e.g., buttons, check boxes, menus, etc.) for various roof modeling tasks, such as setting reference points for the images, setting the vertical (Z) axis for the images, switching between different images, saving the model, and the like. Each of the images **402**-**406** provides a different view of the building roof **407**. In particular, images **402**-**406** respectively provide substantially top-down, south, north, west, and east views of the building roof **407**. Each image **402**-**406** includes four marker controls (also called "reference points" or "registration markers") that are used by the operator to set reference points in the image for purposes of image registration. The registration markers will be described further with respect to an enlargement of image portion **408** described with respect to FIGS. **4**B-**4**C, below.

FIGS. **4**B-**4**C show an enlarged view of image portion **408** during the process of image registration for image **402**, which provides a top-down view of the building roof **407**. As shown in FIG. **4**B, image portion **408** includes the building roof **407** and registration markers **410**-**413**. The markers **410**-**413** are interactive user interface controls that can be directly manipulated (e.g., moved, rotated, etc.) by the operator in order to specify points to use for purposes of image registration. In particular, image registration includes determining a transformation between each of one or more images and a uniform 3D reference grid. The uniform 3D reference grid is used as a coordinate system for a 3D model of the roof. By registering multiple images to the reference grid, an operator may indicate a roof feature on an image (such as a roof edge), which may then be translated from the coordinate system of the image to the coordinate system of the reference grid, for purposes of including the indicated feature in the 3D model.

Marker **410** is an origin marker control, and includes arms **410***a*-**410***c*. Arms **410***a* and **410***b* are horizontal arms that are utilized to specify the X and Y axes (e.g., the horizontal plane) of the reference grid. Arm **410***c* is a vertical arm that may be utilized to specify the Z axis (e.g., the vertical axis) of the reference grid. The use of the vertical arm to specify the Z axis will be further described with respect to FIG. **4**E, below.

Typically, markers **410**-**413** are color coded, such that they may be distinguished from one another. For example, marker **411**-**413** may be respectively colored red, blue, and green. Origin marker **410** has a different appearance than markers **411**-**413**, so may be of any color. In other embodiments, markers **411**-**413** may be distinguished in other ways, such as by utilizing different sized dashed lines, different line thicknesses, etc. In still other embodiments, markers are not distinguished any way from each other, such as by being of uniform shape, color, etc.

FIG. **4**C shows image portion **408** with markers **410**-**413** after they have been placed by an operator. Typically, registration markers are placed at four spatially distributed corners of the roof. As shown in FIG. **4**C, the operator has placed markers **410**-**413** at four different corners of the building roof **407**. In particular, the operator first placed the origin marker **410** at the lower left corner of the building roof **407**, and has adjusted (e.g., rotated) the arms **410***a* and **410***b* to align with the major horizontal axes of the roof. By adjusting the arms **410***a* and **410***b* of the origin marker **410**, the rotational orientation of markers **411**-**413** is automatically adjusted by the roof estimation system. Next, the operator places markers **411**-**413** on some other corners of the roof. In general, the operator can place registration marker over any roof feature, but roof corners are typically utilized because they are more easily identified by the operator. After the operator is satisfied with the placement of markers **410**-**413**, the operator typically registers a next image of the building roof **407**, as will be described next.

FIGS. **4**D-**4**F illustrate image registration for image **404**, which provides a north view of the building roof **407**. In particular, FIG. **4**D shows the user interface screen **400** described with reference to FIG. **4**A. Here, image **402** has been minimized, while image **404** has been enlarged so that the operator may register that image by placing markers on image **404**, as will be described below with respect to an enlarged view of image portion **418**.

FIG. **4**E shows an enlarged view of image portion **418** during the process of image registration for image **404**. Image portion **418** includes the building roof **407** and registration markers **420**-**423**. Markers **420**-**423** respectively correspond to markers **410**-**413** described above. In particular, marker **420** is an origin marker control that includes arms **420***a*-**420***c*. Arms **420***a* and **420***b* are horizontal arms that are utilized to specify the X and Y axes of the reference grid. Arm **420***c* is a vertical arm that may be utilized to specify the Z axis of the reference grid.

In the example of FIG. **4**E, the operator has moved each of markers **420**-**423** to a corner of the roof **407**. Note that the markers **420**-**423** are moved to roof corners that correspond to those selected by the operator with markers **410**-**413**, as described with reference to FIG. **4**C. In particular, origin marker **420** has been moved to the corner of the roof **407** selected with origin marker **410** in image **408**; marker **421** has been moved to the corner selected with marker **411** in image **408**; marker **422** has been moved to the corner selected with marker **412** in image **408**; and marker **423** has been moved to the corner selected with marker **413** in image **408**. In addition, markers **420**-**423** have been rotated, by operator rotation of the origin marker **420**, to align with the major axes of the roof **407**.

As noted, the operator can utilize the origin marker **420** to specify the vertical axis of the reference grid. In particular, the operator can adjust (e.g., by dragging with a mouse or other pointing device) arm **420***c* of marker **420** to specify the ver-

tical (Z) axis of the image. In some cases, aerial images may include some amount of lean, due to the orientation of the aircraft during image capture. For example, pitch, yaw, or roll of an aircraft during the course of image capture may result in images that are misaligned with respect to the vertical axis of the building and its roof. Typically, an operator may adjust arm **420***c* to line up with a feature of a building or roof that is known to be substantially vertical, such as a wall of a house or a chimney. Then, based on the angle of arm **420***c* with respect to the vertical axis of the image, the roof estimation system can determine a correction between the reference grid and the image.

FIG. **4**F shows an enlarged view of image portion **418** after registration of image **404**. Once the operator has placed and adjusted markers **420-423**, the operator may direct (e.g., by clicking a button) the roof estimation system to register the image to the reference grid, based on the positions and orientations of markers **420-423**. Once the roof estimation system registers the image, it provides the operator with feedback so that the operator may determine the correctness or accuracy of the registration.

In the example of FIG. **4**F, the operator has directed the roof estimation system to register image **404**, and the roof estimation system has updated image portion **418** with registration indicators **430-433**. Registration indicators **430-433** provide the operator with feedback so that the operator may judge the accuracy of the registration of image **404**.

Registration indicator **430** is an origin registration indicator that includes two arms **430***a*-**430***b* and three reference grid indicators **430***c*-**430***e*, shown as dashed lines. The reference grid indicators **430***c*-**430***e* show the vertical axis (**430***c*) and the two horizontal axes (**430***d* and **430***e*) of the reference grid determined based on the placement and orientation of the markers **420-423**. Arms **430***a* and **430***b* correspond to the placement of arms **420***a*-**420***c* of origin marker **420**. If the arms **430***a* and **430***b* do not substantially align with the corresponding reference grid indicators **430***e* and **430***d*, then the determined reference grid is out of alignment with the specified axes of the house. Typically, an operator will return to the view of FIG. **4**E to make adjustments to origin marker, such as adjusting one or more of the vertical or horizontal axes, in order to refine the registration of the image. Although the arms **430***a*-**430***b* and the reference grid indicators **430***c*-**430***e* are here illustrated as solid and dashed lines, in other embodiments they may be color coded. For example, arms **430***a*-**430***b* may be red, while reference grid indicators **430***c*-**430***e* may be blue.

Registration indicators **431-433** provide the operator with information regarding the accuracy of the placement of markers **421-423**. In particular, each registration indicator **431-433** includes a solid crosshairs and a reference indicator, shown for example as a dashed line **432***a*. The crosshair of a registration indicator corresponds to the placement of a marker. For example, the crosshairs of registration indicator **431** corresponds to the placement of marker **421** in FIG. **4**E. If the reference indicator intersects the center (or substantially near the center) of the crosshairs of a registration indicator, then the operator knows that the placement of the corresponding marker is accurate. On the other hand, if the reference indicator does not intersect the center of the crosshairs of a registration indicator, then the operator knows that the placement of the corresponding marker is inaccurate. Typically, such an inaccuracy arises when the placement of markers in the top view of the roof does not agree with (correspond to) the placement of corresponding markers in another view of the roof. In such cases, the operator can return to the view of FIG. **4**C or **4**E to adjust the position of one or more markers.

After registering image **404**, the operator will proceed to register additional images of the building roof **407** utilizing a process similar to that described above. In this example, the operator will register images **403**, **405**, and **406**. Although the operator is here described as registering a total of five images, in other cases more or fewer images may be registered.

B. Roof Model Construction

FIGS. **5**A-**5**D and **6**A-**6**C generally illustrate aspects of the process of roof model generation based on multiple registered images. In particular, these figures illustrate the construction of a roof model by an operator. Model generation/construction may include identification of roof features shown in various images of the roof, such as edges, planar sections, vertexes, and the like, as well as determination of roof pitch and other dimensional attributes of the roof. Each identified roof feature is incorporated by the roof estimation system into a 3D model of the roof, based on a translation between an image in which the feature is identified and the reference grid, as determined by the process described with reference to FIGS. **4**A-**4**F, above.

FIGS. **5**A-**5**D are screen displays illustrating pitch determination in an example embodiment. In particular, FIG. **5**A shows the user interface screen **400** after images **402-406** have been registered. In this example, the operator is using a pitch determination control (also called a "pitch determination marker" or "pitch determination tool") to specify the pitch of a planar roof section of the building roof **407** visible in image **406**. The pitch determination control will be further described in FIG. **5**B, below, with respect to an enlargement of image portion **508**.

FIG. **5**B shows an enlarged view of image portion **508** during the process of pitch determination for image **406**, which provides an east perspective view of the building roof **407**. As shown in FIG. **5**B, the image portion **508** includes the building roof **407** and a pitch determination marker **510** (also called a "protractor tool"). The pitch determination marker **510** is an interactive user interface control that can be directly manipulated by the operator in order to specify the pitch of a section of the building roof **407**.

The pitch determination marker **510** includes arms **510***a*-**510***d*. Arms **510***a*-**510***c* are axes, which are automatically aligned, based on the registration of image **406**, with the major (X, Y, and Z) axes of the building roof. Arm **510***d* is a "protractor" arm that is adjustable by the operator to specify roof pitch.

The marker **510** is typically first moved by the operator to a convenient location on the building roof **407**, usually corner of a planar section of the roof **407**. Next, the operator adjusts arm **510***d* so that it substantially aligns with the sloped edge of the planar roof section. Then, the roof estimation system determines the pitch of the roof section, based on the configuration of the marker **510** with respect to the image and the reference grid.

After specifying the pitch of a planar roof section, the operator will typically specify other information about the planar roof section, such as its outline, as will be described with reference to FIGS. **6**A-**6**D. Note that as the operator provides additional information about the geometry of the roof **407**, the roof estimation system may automatically determine the pitch and/or other features of at least some of the other planar roof sections, based on the provided geometric information and/or assumptions about roof symmetry or other standard architectural practices.

FIG. **5**C shows a second type of pitch determination marker being used in the context of image **403** which provides a south perspective view of the building roof **407**. The illustrated pitch determination marker may be used in addition to, or

instead of, the pitch determination marker **510** described with respect to FIGS. **5**A-**5**B, above. In particular, FIG. **5**C shows a pitch determination marker **520** (also called an "envelope tool") that includes surfaces **520***a* and **520***b*. The pitch determination marker **520** is an interactive user interface control that can be directly manipulated by the operator in order to specify the pitch of a section of the building roof **407**. In particular, the pitch determination marker **520** may be moved and/or adjusted so that it appears to lie substantially atop two adjacent planar sections of roof **407**.

FIG. **5**D shows the pitch determination marker **520** after the operator has used it to specify the pitch of two sections of roof **407**. Here, the operator has moved the marker **520** to a position in which the spine of the marker **520** is substantially aligned with the ridge line of roof **407**. Then, the operator has adjusted the angle of the surfaces **520***a* and **520***b* so that they appear to lie substantially atop corresponding sections of roof **407**. Then, the roof estimation system determines the pitch of the roof sections, based on the configuration of the marker **520** with respect to the image and the reference grid. Also illustrated are pitch indicators **521** and **522**. Pitch indicator **521** corresponds to the measured pitch of surface **520***a*, and pitch indicator **522** corresponds to the measured pitch of surface **520***b*. As the operator adjusts the angle of surfaces **520***a* and/or **520***b*, the corresponding pitch indicators **521**-**522** are automatically updated to reflect the determined pitch. In this example, the pitch of both surfaces is given as 4 inches of rise per foot of run.

The envelope pitch determination marker **520** may be adjusted in other ways, to specify pitches for types of roofs other than the gabled roof shown in image **403**. For example, when measuring pitch of roof sections that form a roof hip, point **520***c* may be manipulated by the operator, such as by dragging it to the left or right, to adjust the shape of the surfaces **520***a* and **520***b*, so that the surfaces align with the edges formed by the intersection of the sections that form the roof hip.

FIGS. **6**A-**6**D are screen displays illustrating model construction and concurrent display of operator specified roof features in an example embodiment. In particular, FIGS. **6**A-**6**D illustrate the construction of a three dimensional wire frame model of a building roof, based on the specification of roof features by an operator. In addition, FIGS. **6**A-**6**D illustrate the concurrent display of operator specified roof features in multiple views of a building roof.

FIG. **6**A shows the user interface screen **400** after images **402**-**406** have been registered, and after roof pitches have been determined. In this example, the operator is specifying sections of roof **407**, visible in image **406**, that are to be added to a 3D wire frame model of the roof **407** maintained by the roof estimation system. The specification of roof sections will be further described with reference to enlarged portion **608** of image **406** in FIG. **6**B, below. In addition, as the operator specifies roof sections in image **406**, the roof estimation system concurrently displays the specified roof sections in each of the other images **402**-**405**. The concurrent display of operator specified roof features will be further described with reference to enlarged portion **609** of image **402** in FIG. **6**C, below.

FIG. **6**B is an enlarged view of image portion **608** during the process of wire frame model construction in the context of image **406**, which provides an east perspective view of the building roof **407**. As shown in FIG. **6**B, the image portion **608** includes the building roof **407**, drawing tool **610**, and wire frame **611**. The drawing tool **610** (also called a "drawing marker" or a "drawing control") is an interactive user interface control that can be directly manipulated by the operator in order to specify roof features, such as edges, ridges, valleys, corners, etc. In the illustrated embodiment, the operator uses the drawing tool **610** to trace or outline planar sections of the roof **407**, leading to the generation of wire frame **611**. The drawing tool **610** may be used to establish a series of connected line segments that result in a closed polygon representing a planar roof section. As the operator specifies a planar roof section in this manner, the roof estimation system determines, based on the image and the reference grid, the geometry of the planar roof section, and includes (adds) the specified planar roof section in a 3D model that corresponds to roof **407**.

FIG. **6**C is an enlarged view of image portion **609** illustrating the concurrent display of operator specified roof features, in the context of image **402**, which provides a top plan view of the building roof **407**. As the operator specifies roof sections as described with respect to FIG. **6**B, the roof estimation system concurrently displays the specified roof features in one or more of the other images displayed by the user interface screen **400**. More specifically, image portion **609** includes building roof **407** and wire frame **612**. Wire frame **612** corresponds to wire frame **611** constructed by the operator with reference to FIG. **6**B, except that wire frame **612** is automatically displayed as a projection from the 3D model into the top-down view of image **402**. Changes that the operator makes to wire frame **611** are concurrently displayed by the roof estimation system as wire frame **612** in image portion **609**. For example, if a new planar roof section is added by the operator to wire frame **611**, the new planar roof section is automatically displayed in wire frame **612**. By concurrently displaying operator identified features in multiple views of building roof **407**, the operator obtains feedback regarding the correctness and/or accuracy of the 3D model or other aspects of the model generation process, such as image registration and pitch determination.

Generally, the roof estimation system can be configured to concurrently display any operator-identified features, such as corners, ridges, valleys, planar sections, and the like, in multiple views of a building.

Furthermore, the concurrently displayed wire frame **612** is an interactive user interface element, in that the operator can make changes to the wire frame **612**, which are then concurrently displayed in wire frame **611**. Wire frames similar to those described above are also projected by the roof estimation system into images **403**, **404**, and **405** displayed by the user interface screen **400**. In this manner, the operator can switch between various images of the building roof **407**, making refinements to the 3D model by adjusting the wire frame in whichever image is more convenient and/or provides a more suitable perspective/view of the model.

FIG. **6**D shows the user interface screen **400** during construction of a 3D model of the building roof **407**. In particular, the user interface **400** includes a shaded wire frame **613** representation of the 3D model constructed as described above. In this view, the operator can review the wire frame **613** in isolation from any images to determine whether the wire frame **613** accurately represents the building roof **407**. The wire frame **613** is an interactive user interface component, in that it can be directly manipulated (e.g., moved, rotated, resized, etc.). In some embodiments, manipulating the wire frame **613**, such as by changing its shape, results in corresponding changes in the underlying 3D model.

C. Roof Model Review

FIGS. **7**A-**7**C are screen displays illustrating roof model review in an example embodiment. In particular, FIGS. **7**A-**7**C illustrate various techniques to facilitate the review of a roof model by an operator. Reviewing the roof model may

include reviewing roof section pitches (e.g., to determine whether they conform to the building roof and/or standard construction practices), reviewing the shape and/or location of the roof model (e.g., to determine whether it substantially conforms to the building roof), etc.

FIG. **7**A shows the user interface screen **400** after the operator has constructed a model of the roof **407** using one or more of the images **402**-**406**. In this example, a wire frame has been projected onto (superimposed upon) image **402** and annotated with roof section pitches, as will be described further with respect to enlarged portion **708** of image **402** in FIG. **7**B, below.

FIG. **7**B is an enlarged view of image portion **708** during the process of roof model review in the context of image **402**, which provides a substantially top plan view of the building roof **407**. As shown in FIG. **7**B, the image portion **708** includes a wire frame **710** and labels **711***a*-**711***c* that indicate pitches of corresponding sections of roof **407**. The wire frame **710** and the illustrated pitches are determined by the roof estimation system based on the pitch determination described with respect to FIGS. **5**A-**5**D, above, and the operator's specification of the wire frame model described with respect to FIGS. **6**A-**6**D, above.

The wire frame **710** includes multiple vertexes connected by line segments. Each vertex includes a handle, such as handle **710***a*. The handles may be directly manipulated (individually or in groups) by the operator to make adjustments/modifications to the wire frame **710**. For example, when an operator drags handle **710***a* to a new location, the ends of the two line segments connected to handle **710***a* will also move to the new location.

FIG. **7**C is an alternative view of the 3D model of roof **407** during the process of roof model review. In FIG. **7**C, the user interface screen **400** includes a wire frame **720** representation of the 3D model of the roof **407**. The wire frame **720** consists of multiple line segments corresponding to edges of planar roof sections. Each line segment is annotated with a label, such as label **723**, indicating the determined length of the corresponding roof section edge. Furthermore, some of the line segments indicate that they correspond to a particular roof feature. For example, line segments **721** and **722** may be colored (e.g., red) so as to indicate that they correspond to roof ridges. Other line segments may be differently colored (e.g., blue) so as to indicate a correspondence to roof valleys or other features. In addition, the wire frame **720** may be directly manipulated by the operator in order to make adjustments to the underlying model of the roof **407**. For example, the operator could increase or decrease the length of line segment **721**, resulting in a change in the corresponding feature of the 3D model of roof **407**.

Note that although the operator is shown, in FIGS. **5**-**7** above, operating upon a total of five images, in other cases, fewer images may be used. For example, in some cases fewer images may be available, or some images may provide obstructed views of the building roof, such as due to tree cover, neighboring buildings, etc.

3. Implementation Techniques

FIG. **8** is an example block diagram of a computing system for practicing embodiments of a roof estimation system. FIG. **8** shows a computing system **800** that may be utilized to implement a Roof Estimation System ("RES") **810**. One or more general purpose or special purpose computing systems may be used to implement the RES **810**. More specifically, the computing system **800** may comprise one or more distinct computing systems present at distributed locations. In addition, each block shown may represent one or more such blocks as appropriate to a specific embodiment or may be combined with other blocks. Moreover, the various blocks of the RES **810** may physically reside on one or more machines, which use standard inter-process communication mechanisms (e.g., TCP/IP) to communicate with each other. Further, the RES **810** may be implemented in software, hardware, firmware, or in some combination to achieve the capabilities described herein.

In the embodiment shown, computing system **800** comprises a computer memory ("memory") **801**, a display **802**, one or more Central Processing Units ("CPU") **803**, Input/Output devices **804** (e.g., keyboard, mouse, joystick, track pad, CRT or LCD display, and the like), other computer-readable media **805**, and network connections **806**. The RES **810** is shown residing in memory **801**. In other embodiments, some portion of the contents, some of, or all of the components of the RES **810** may be stored on and/or transmitted over the other computer-readable media **805**. The components of the RES **810** preferably execute on one or more CPUs **803** and generate roof estimate reports, as described herein. Other code or programs **830** (e.g., a Web server, a database management system, and the like) and potentially other data repositories, such as data repository **820**, also reside in the memory **801**, and preferably execute on one or more CPUs **803**. Not all of the components in FIG. **8** are required for each implementation. For example, some embodiments embedded in other software do not provide means for user input, for display, for a customer computing system, or other components.

In a typical embodiment, the RES **810** includes an image acquisition engine **811**, a roof modeling engine **812**, a report generation engine **813**, an interface engine **814**, and a roof estimation system data repository **816**. Other and/or different modules may be implemented. In addition, the RES **810** interacts via a network **850** with an image source computing system **855**, an operator computing system **865**, and/or a customer computing system **860**.

The image acquisition engine **811** performs at least some of the functions of the image acquisition engine **101** described with reference to FIG. **1**. In particular, the image acquisition engine **811** interacts with the image source computing system **855** to obtain one or more images of a building, and stores those images in the RES data repository **816** for processing by other components of the RES **810**. In some embodiments, the image acquisition engine **811** may act as an image cache manager, such that it preferentially provides images to other components of the RES **810** from the RES data repository **816**, while obtaining images from the image source computing system **855** when they are not already present in the RES data repository **816**. In other embodiments, images may be obtained in an "on demand" manner, such that they are provided, either by the image acquisition engine **811** or the image source computing system **855**, directly to modules of the RES **810** and/or the operator computing system **865**, without intervening storage in the RES data repository **816**.

The roof modeling engine **812** performs at least some of the functions of the roof modeling engine **102** described with reference to FIG. **1**. In particular, the roof modeling engine **812** generates a model based on one or more images of a building that are obtained from the RES data repository **816** or directly from the image source computing system **855**. As noted, model generation may be performed semi-automatically, based on at least some inputs received from the computing system **865**. In addition, at least some aspects of the model generation may be performed automatically, based on image processing and/or image understanding techniques. After the roof modeling engine **812** generates a model, it

stores the generated model in the RES data repository **816** for further processing by other components of the RES **810**.

The report generation engine **813** performs at least some of the functions of the report generation engine **103** described with reference to FIG. **1**. In particular, the report generation engine **813** generates roof reports based on models stored in the RES data repository **816**. Generating a roof report may include preparing one or more views of a given 3D model of a roof, annotating those views with indications of various characteristics of the model, such as dimensions of sections or other features (e.g., ridges, valleys, etc.) of the roof, slopes of sections of the roof, areas of sections of the roof, etc. In some embodiments, the report generation engine **813** facilitates transmission of roof measurement information that may or may not be incorporated into a roof estimate report. For example, the roof generation engine **813** may transmit roof measurement information based on, or derived from, models stored in the RES data repository **816**. Such roof measurement information may be provided to, for example, third-party systems that generate roof estimate reports based on the provided information.

The interface engine **814** provides a view and a controller that facilitate user interaction with the RES **810** and its various components. For example, the interface engine **814** implements a user interface engine **104** described with reference to FIG. **1**. Thus, the interface engine **814** provides an interactive graphical user interface that can be used by a human user operating the operator computing system **865** to interact with, for example, the roof modeling engine **812**, to perform functions related to the generation of models, such as point registration, feature indication, pitch estimation, etc. In other embodiments, the interface engine **814** provides access directly to a customer operating the customer computing system **860**, such that the customer may place an order for a roof estimate report for an indicated building location. In at least some embodiments, access to the functionality of the interface engine **814** is provided via a Web server, possibly executing as one of the other programs **830**.

In some embodiments, the interface engine **814** provides programmatic access to one or more functions of the RES **810**. For example, the interface engine **814** provides a programmatic interface (e.g., as a Web service, static or dynamic library, etc.) to one or more roof estimation functions of the RES **810** that may be invoked by one of the other programs **830** or some other module. In this manner, the interface engine **814** facilitates the development of third-party software, such as user interfaces, plug-ins, adapters (e.g., for integrating functions of the RES **810** into desktop applications, Web-based applications, embedded applications, etc.), and the like. In addition, the interface engine **814** may be in at least some embodiments invoked or otherwise accessed via remote entities, such as the operator computing system **865**, the image source computing system **855**, and/or the customer computing system **860**, to access various roof estimation functionality of the RES **810**.

The RES data repository **816** stores information related to the roof estimation functions performed by the RES **810**. Such information may include image data **105**, model data **106**, and/or report data **107** described with reference to FIG. **1**. In addition, the RES data repository **816** may include information about customers, operators, or other individuals or entities associated with the RES **810**.

In an example embodiment, components/modules of the RES **810** are implemented using standard programming techniques. For example, the RES **810** may be implemented as a "native" executable running on the CPU **803**, along with one or more static or dynamic libraries. In other embodiments, the RES **810** is implemented as instructions processed by virtual machine that executes as one of the other programs **830**. In general, a range of programming languages known in the art may be employed for implementing such example embodiments, including representative implementations of various programming language paradigms, including but not limited to, object-oriented (e.g., Java, C++, C#, Matlab, Visual Basic.NET, Smalltalk, and the like), functional (e.g., ML, Lisp, Scheme, and the like), procedural (e.g., C, Pascal, Ada, Modula, and the like), scripting (e.g., Perl, Ruby, Python, JavaScript, VBScript, and the like), declarative (e.g., SQL, Prolog, and the like).

The embodiments described above may also use well-known synchronous or asynchronous client-server computing techniques. However, the various components may be implemented using more monolithic programming techniques as well, for example, as an executable running on a single CPU computer system, or alternatively decomposed using a variety of structuring techniques known in the art, including but not limited to, multiprogramming, multithreading, client-server, or peer-to-peer, running on one or more computer systems each having one or more CPUs. Some embodiments execute concurrently and asynchronously, and communicate using message passing techniques. Equivalent synchronous embodiments are also supported by an RES implementation. Also, other functions could be implemented and/or performed by each component/module, and in different orders, and by different components/modules, yet still achieve the functions of the RES.

In addition, programming interfaces to the data stored as part of the RES **810**, such as in the RES data repository **816**, can be available by standard mechanisms such as through C, C++, C#, and Java APIs; libraries for accessing files, databases, or other data repositories; through scripting languages such as XML; or through Web servers, FTP servers, or other types of servers providing access to stored data. For example, the RES data repository **816** may be implemented as one or more database systems, file systems, memory buffers, or any other technique for storing such information, or any combination of the above, including implementations using distributed computing techniques.

Also, the example RES **810** can be implemented in a distributed environment comprising multiple, even heterogeneous, computer systems and networks. For example, in one embodiment, the image acquisition engine **811**, the roof modeling engine **812**, the report generation engine **813**, the interface engine **814**, and the data repository **816** are all located in physically different computer systems. In another embodiment, various modules of the RES **810** are hosted each on a separate server machine and are remotely located from the tables which are stored in the data repository **816**. Also, one or more of the modules may themselves be distributed, pooled or otherwise grouped, such as for load balancing, reliability or security reasons. Different configurations and locations of programs and data are contemplated for use with techniques as described herein. A variety of distributed computing techniques are appropriate for implementing the components of the illustrated embodiments in a distributed manner including but not limited to TCP/IP sockets, RPC, RMI, HTTP, Web Services (XML-RPC, JAX-RPC, SOAP, and the like).

Furthermore, in some embodiments, some or all of the components of the RES are implemented or provided in other manners, such as at least partially in firmware and/or hardware, including, but not limited to one or more application-specific integrated circuits (ASICs), standard integrated circuits, controllers (e.g., by executing appropriate instructions, and including microcontrollers and/or embedded control-

lers), field-programmable gate arrays (FPGAs), complex programmable logic devices (CPLDs), and the like Some or all of the system components and/or data structures may also be stored (e.g., as software instructions or structured data) on a computer-readable medium, such as a hard disk, a memory, a network, or a portable media article to be read by an appropriate drive or via an appropriate connection. The system components and data structures may also be stored as data signals (e.g., by being encoded as part of a carrier wave or included as part of an analog or digital propagated signal) on a variety of computer-readable transmission mediums, which are then transmitted, including across wireless-based and wired/cable-based mediums, and may take a variety of forms (e.g., as part of a single or multiplexed analog signal, or as multiple discrete digital packets or frames). Such computer program products may also take other forms in other embodiments. Accordingly, embodiments of this disclosure may be practiced with other computer system configurations.

FIG. **9** is an example flow diagram of an image registration routine provided by an example embodiment. The illustrated routine **900** may be provided by, for example, execution of the roof estimation system **810** described with respect to FIG. **8**. The illustrated routine **900** facilitates image registration based upon operator indicated registration points and/or image lean corrections.

More specifically, the routine begins in step **901**, where it displays, on a user interface screen, an aerial image of a building having a roof. As part of the user interface screen, the routine also displays user interface controls such as markers that may be used by an operator for purposes of image registration and/or lean correction, as described with reference to FIG. **4**A, above.

In step **902**, the routine receives, via one or more registration markers, indications of one or more points on the aerial image. The registration markers are manipulated by the operator to specify points on the aerial image, as described with reference to FIGS. **4**A-**4**E. Typically, the points are visually identifiable features, such as corners of the roof of the building. For example, if the roof has four corners (e.g., a northwest, southwest, northeast, and southeast corner) the operator may place one registration marker on each of the four corners as shown in the aerial image. Then, the positions (e.g., coordinates on the aerial image) of the markers are transmitted to the routine for use in registering the aerial image, as described below.

In step **903**, the routine receives, via a lean correction marker, an indication of the vertical axis of the building roof. In at least some cases, the aerial image of the building is out of alignment with respect to the vertical axis of the building. This may be caused, for example, by pitch, roll, and/or yaw experienced by the aircraft during the process of photographing the building. To correct for such misalignment, the lean correction marker is manipulated by the operator to indicate a vertical axis of the building. Typically, the operator aligns the lean correction marker with known, substantially vertical feature of the building, such as a chimney, wall corner, etc., as described with reference to FIG. **4**E, above. After the operator has aligned the lean correction marker, the position (e.g., angle of the marker, coordinates of the endpoints of the marker, etc.) of the lean correction marker is transmitted to the routine for use in registering the aerial image, as described below.

Particular benefits may be obtained from lean correction performed in the context of an overhead, or "top down," view. An "overhead lean" occurs when the camera is not directly overhead with respect to the building when the photo is taken. In some cases, leans in excess of 5 degrees have been observed in "top down" photos. Furthermore, unlike oblique, perspective views, a top-down lean is typically less likely to include a convenient visual marker that provides sufficient angle to assess the lean direction and magnitude, such as the edge of the building or a tall chimney. An overhead lean affects the perceived location of the roof lines in a top down view. This effect is amplified as the pitch of the roof increases and/or as the vertical separation between disconnected roof sections increases. Without lean correction, superimposing a wire frame over the visible ridgelines (and other features of a building that reside at different elevations) may produce asymmetries in otherwise symmetric structures. Further, an absence of lean correction may introduce errors in pitch estimation, as the wire frame may not appear consistent between top and oblique view points. More specifically, without top view lean correction, the positions for the roof lines in an otherwise correct (i.e., accurate with respect to the actual geometry of the roof) wire frame will typically not line up on the visible roof lines in the overhead reference photo. This often leads the user (or software) to either introduce errors by incorrectly drawing the wire frame to the image lines or perform a subjective determination of where and how to shift the wire frame lines off the image lines to produce a correct model. Top view lean correction allows the roof estimation system to trace to, or substantially to, the actual roof lines seen in the top image while still producing an accurate wire frame model.

Image misalignment may be specified in other ways. For example, in other embodiments, the operator may instead rotate the image to a position in which the building appears to be in a substantially vertical position. Then, the angle of rotation of the image may be transmitted to the routine for use in registering the aerial image.

In step **904**, the routine registers, based on the received indications of the points and/or the received indication of the vertical axis, the aerial image to a reference grid. Registering the image to a reference grid may include determining a transformation between the reference grid and the image, based on the indicated points and/or the indicated vertical axis. Determining such a transformation may be based on other information as well, such as meta-information associated with the aerial image. In some embodiments, the aerial image has corresponding meta-information that includes image capture conditions, such as camera type, focal length, time of day, camera position (e.g., latitude, longitude, and/or elevation), etc.

In step **905**, the routine determines whether there are additional aerial images to be registered, and if so, returns to step **901**, else proceeds to step **906**. During execution of the loop of steps **901**-**905**, the operator typically indicates, for each registration marker, the same feature (e.g., corner) of the roof as shown in each of multiple images, such that the routine can register the multiple images to a single, uniform reference grid. Upon completion of the registration process, the routine has determined a uniform coordinate system for the multiple aerial images, for use during other phases of model construction, such as pitch determination or feature identification.

In step **906**, the routine generates a three-dimensional model based at least in part on the aerial image(s) and the reference grid. As discussed above with reference to FIGS. **5**A-**5**D and **6**A-**6**D, model generation includes identification of roof features shown in various images of the roof, such as edges, planar sections, vertexes, and the like, as well as determination of roof pitch and other dimensional attributes of the roof. In other embodiments, the routine performs other functions with the registered images, such as storing them for later use (e.g., by an automated model generation module), trans-

mitting them to another computing (e.g., for use in a third-party design application), etc. After step **906**, the routine ends.

Note that in at least some embodiments, aspects of the routine **900** may be performed in an automated manner. For example, operations discussed above as being performed by an operator, such as the determination of the location of image registration points of step **902** and/or the indication of lean of step **903**, may be performed by automated image processing techniques.

FIG. **10** is an example flow diagram of a pitch determination routine provided by an example embodiment. The illustrated routine **1000** may be provided by, for example, execution of the roof estimation system **810** described with respect to FIG. **8**. The illustrated routine **1000** facilitates the determination of the pitch of a section of a roof, by displaying a pitch determination marker and modifying a 3D model of a roof based on an indication of roof pitch received via the pitch determination marker.

More specifically, the routine begins at step **1001** where it displays an aerial image of a building having a roof comprising a plurality of planar roof sections that each have a corresponding pitch. The aerial image is displayed in the context of a user interface screen, such as is described with reference to FIGS. **4**A-**6**C, above. The aerial images may be received from, for example, the image source computing system **855** and/or from the RES data repository **816** described with reference to FIG. **8**. As discussed above, aerial images may be originally created by cameras mounted on airplanes, balloons, satellites, etc. In some embodiments, images obtained from ground-based platforms (e.g., vehicle-mounted cameras) may be used instead or in addition.

In step **1002**, the routine displays a pitch determination marker operable to indicate pitch of a planar roof section. The pitch determination marker may be, for example, a pitch determination marker **510** ("protractor tool") or **520** ("envelope tool"), such as are respectively described with respect to FIGS. **5**B and **5**C, above. The routine displays the pitch determination marker by, for example, presenting it on a user interface screen displayed on a computer monitor or other display device. The pitch determination marker is a direct manipulation user interface control, in that an operator may manipulate it (e.g., adjust an angle, change its shape, alter its position, etc.) in order to indicate pitch of a planar roof section. Additional details regarding pitch determination controls are provided with respect to FIGS. **5**A-**5**D, above.

In step **1003**, the routine receives, via the displayed pitch determination marker, an indication of the pitch of one of the plurality of planar roof sections of the roof of the building. Receiving an indication of the pitch includes receiving an indication (e.g., via an event, callback, etc.) that the marker has been manipulated by the operator, and then determining an angle based on the shape and/or position of the marker. In some embodiments, such an indication may be received on an event driven basis, such as every time the marker is manipulated in some manner. In other embodiments, the routine may poll the marker from time to time to determine its current state. In addition, the operator may explicitly indicate that the current state of the marker is to be transmitted to the routine, such as by pressing a button or other indication.

In step **1004**, the routine modifies a three-dimensional model of the roof based on the received indication of the pitch of the one planar roof section. Modifying the 3D model of the roof includes associating the indicated pitch with a portion of the model corresponding to the one planar roof section. For example, the 3D model may include one or more data structures representing planar roof sections, and the indicated pitch may be included as part of the data structure representing the one planar roof section. In some embodiments, the 3D model may not at this point include representations of the planar roof sections, such as because the operator has not yet specified them. In such a case, the routine may store the indicated pitch in association with the location and orientation at which the pitch was specified by the operator, as determined from the aerial image. Then, at a later time, when the operator specifies a roof section that has the same orientation as the stored pitch and that includes or is near the stored location, the roof estimation system can store the indicated pitch in association with the specified roof section.

After step **1004**, the routine ends. In other embodiments, the routine may instead return to step **1001**, to determine the pitch for another planar roof section (of the same or different roof).

FIG. **11** is an example flow diagram of concurrent feature display routine provided by an example embodiment. The illustrated routine **1100** may be provided by, for example, execution of the roof estimation system **810** described with respect to FIG. **8**. The illustrated routine **1100** concurrently displays operator indicated features in multiple aerial images of a building roof.

More specifically, the routine begins in step **1101**, where it displays a first and a second aerial image of a building having a roof, each of the aerial images providing a different view of the roof of the building. The aerial images are displayed in the context of a user interface screen, such as is described with reference to FIGS. **6**A-**6**C, above.

In step **1102**, the routine receives an indication of a feature of the building shown in the first aerial image. The indication is typically received via a user interface control, such as a drawing tool or marker, upon its manipulation by an operator. For example, the operator may manipulate a drawing tool in order to specify one or more features of the building roof, such as a corner on the roof, an edge of the roof, an outline of a section of the roof, etc. In one embodiment, the operator utilizes a drawing tool to indicate roof section corner points and roof section edges connecting those corner points. Additional details regarding feature indication are provided with respect to FIGS. **6**A-**6**C, above.

In step **1103**, the routine modifies a three-dimensional model of the roof based on the received indication of the feature of the building. Modifying the 3D model may include adding or updating the indicated feature to a wire frame model of the roof. For example, if the indicated feature is a roof section corner point, the corner point will be added to the 3D model, along with the location (e.g., the X, Y, and Z position of the point) of the point. The location of the point is automatically determined based on a translation of the position of the point in the image to a point in the uniform reference grid associated with the image. If the indicated feature is a roof section edge, the edge will be added to the 3D model, such as by associating the edge with two points corresponding to the end points of the edge. Higher-level features can also be indicated. For example, a planar roof section may be indicated by "closing" a sequence of two or more connected line segments, to create a closed polygon that represents the outline or perimeter of the planar roof section.

In step **1104**, the routine concurrently displays a projection of the feature from the modified three-dimensional model onto the first and second aerial images. In one embodiment, displaying the feature from the modified three-dimensional model includes projecting the three-dimensional model onto both the first and second aerial images. For example, if the first image (for which the indicated feature was received) provides a west view of the building, and the second image

provides an east view of the building, the routine will concurrently display a projection of the indicated feature from the 3D model onto both the first and second images. The projection of the indicated feature into the second image is based at least in part on a translation from the position of the feature in the reference grid to a position in the second image. In addition, the concurrent display onto two or more images occurs at substantially the same time (within a short time interval, at times that are substantially coincident) as the indication of the feature of the building in step **1102**, giving the operator the illusion that as they are indicating a feature in the first image, the feature is being simultaneously projected into the second image.

After step **1104**, the routine ends. In other embodiments, the routine may instead return to step **1101**, to perform an interactive loop of steps **1101-1104** with the operator, so that the routine can concurrently display multiple features as they are indicated by the operator. Note that in such an embodiment, each iteration of the loop of steps **1101-1104** may be performed at near real-time speeds, so as to provide a fluid, interactive model generation experience for the operator enabling the operator to drag, draw, or otherwise indicate/manipulate features in a first image and view the results of their work concurrently projected into a second image.

All of the above U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet, including but not limited to U.S. Provisional Patent Application No. 61/197,904, entitled "USER INTERFACE SYSTEMS AND METHODS FOR ROOF ESTIMATION," filed Oct. 31, 2008, are incorporated herein by reference, in their entireties.

From the foregoing it will be appreciated that, although specific embodiments have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the present disclosure. For example, the methods, systems, and techniques for generating and providing roof estimate reports discussed herein are applicable to other architectures other than the illustrated architecture or a particular roof estimation system implementation. Also, the methods and systems discussed herein are applicable to differing network protocols, communication media (optical, wireless, cable, etc.) and devices (such as wireless handsets, electronic organizers, personal digital assistants, portable email machines, game machines, pagers, navigation devices such as GPS receivers, etc.). Further, the methods and systems discussed herein may be utilized by and/or applied to other contexts or purposes, such as by or for solar panel installers, roof gutter installers, awning companies, HVAC contractors, general contractors, and/or insurance companies.

The invention claimed is:

1. A computer-implemented method in a roof estimate report system including at least one processor and a memory coupled to the at least one processor, the method comprising:

displaying, by the at least one processor of the roof estimate report system, a plurality of aerial images of a roof at the same time, each of the aerial images providing a different view, taken from a different angle of the same roof;

displaying, by the at least one processor of the roof estimate report system, respective line drawings representing features of the roof, the respective line drawings overlying a first and a second aerial image of the plurality of aerial images of the roof, the line drawing overlying the first aerial image of the roof having features in common with the line drawing overlying the second aerial image of the roof;

in response to user input, changing, by the at least one processor of the roof estimate report system, the line drawing representing a feature of the roof that overlies the first aerial image of the roof;

in response to the changing, making corresponding changes, by the at least one processor of the roof estimate report system, to the line drawing overlying the second aerial image; and

generating and outputting a roof estimate report using a report generation engine, wherein the roof estimate report includes numerical values for corresponding slope, area, or lengths of edges of at least some of a plurality of planar roof sections of the roof, wherein the generated roof estimate report is provided for repair and/or constructing the roof structure of the building.

2. The method of claim **1** further comprising, before the displaying the respective line drawings, modifying a three-dimensional model of the roof based on a received indication of a roof feature by adding a planar roof section to the three-dimensional model.

3. The method of claim **2** wherein the indicated roof feature is at least one of: a point on the roof, a section of the roof, a ridgeline of the roof, a valley of the roof, a rake edge of the roof, an eave of the roof, a hip ridge of the roof, an edge of a section of the roof, and a corner of a section of the roof.

4. The method of claim **1** wherein the displaying the respective line drawings comprises:

displaying the respective line drawing overlying the first aerial image at a first time; and

displaying the respective the line drawing overlying the second aerial image at a second time that is substantially coincident to the first time.

5. The method of claim **1** further comprising receiving an indication of one of the features of the roof at a first time, and wherein the displaying the respective line drawings occurs at a second time that is substantially coincident to the first time.

6. The method of claim **1** wherein the displaying the respective line drawings includes initiating display of a line on the first and second image.

7. The method of claim **1** wherein the first image provides a substantially top plan view of the roof of the building, and wherein the second image provides a perspective view of the roof of the building.

8. The method of claim **1** wherein the first image provides a first perspective view of the roof of the building and the second image provides a second perspective view of the roof of the building.

9. The method of claim **1** further comprising:

transmitting roof measurement information based at least in part on the change of the line drawing representing a feature of the roof that overlies the first aerial image of the roof.

10. The method of claim **1** further comprising:

displaying a marker operable to specify a point on an image;

receiving, via the marker, an indication of a point on the first aerial image; and

registering, based on the received indication of the point, the aerial image to a reference grid corresponding to a three-dimensional model of the roof.

11. The method of claim **1** further comprising:

displaying a lean correction marker operable to indicate a vertical axis of an aerial image;

receiving, via the lean correction marker, an indication of a vertical axis of the first aerial image; and

registering, based on the received indication of the vertical axis, the first aerial image to a reference grid corresponding to a three-dimensional model of the roof.

12. A computing system for generating a roof estimate report, the computing system comprising:

a memory;

at least one processor coupled to the memory; and a roof estimation module that is stored on the memory and that is configured, when executed by at least one processor of the computing system for generating the roof estimate report, to:

overlay a line drawing of a roof feature on corresponding locations of the feature on first and second aerial images of the roof;

in response to user input causing addition of another roof feature in the line drawing overlaid on the first aerial image, make a corresponding addition of the other roof feature to the line drawing overlaid on the second aerial image; and

generate and output a roof estimate report using a report generation engine, wherein the roof estimate report includes numerical values for corresponding slope, area, or lengths of edges of at least some of a plurality of planar roof sections of the roof, wherein the generated roof estimate report is provided for repair and/or constructing the roof structure of the building.

13. The computing system of claim **12** wherein the roof estimation module includes an interactive roof modeling user interface.

14. The computing system of claim **12** wherein the other roof feature is a planar roof section.

15. The computing system of claim **12** wherein the roof estimation module is part of a network accessible roof modeling program executing on the computing system.

16. A non-transitory computer-readable storage medium, having computer executable instructions stored thereon that, when executed by at least one computer processor, cause the at least one processor to enable a computing system to generate a roof estimate report for a building having a roof, by performing a method comprising:

overlaying a line drawing on corresponding locations of a roof feature of the roof on first and second aerial images of the roof, wherein the first aerial image provides a first view of the roof of the building and the second aerial image provides a second view of the roof of the building;

in response to changes in the line drawing overlaid on the first aerial image, displaying corresponding changes to the line drawing overlaid on the second aerial image; and

generate and output a roof estimate report using a report generation engine, wherein the roof estimate report includes numerical values for corresponding slope, area, or lengths of edges of at least some of a plurality of planar roof sections of the roof, wherein the generated roof estimate report is provided for repair and/or constructing the roof structure of the building.

17. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises modifying a three-dimensional model of the roof by adding a planar roof section to the three-dimensional model.

18. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises:

receiving an indication of the roof feature by receiving position information of the feature in the first aerial image;

translating the received position information into position information of the roof feature in a three-dimensional model; and

translating the position information of the feature in the three-dimensional model into position information of the feature in the second aerial image.

19. The non-transitory computer-readable storage medium of claim **16** further comprising:

displaying the roof feature in the first aerial image at a first time; and

displaying the roof feature in the second aerial image at a second time that is within two seconds of the first time.

20. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises displaying a projection of the roof feature onto the first aerial image substantially concurrently with receiving an indication of the roof feature.

21. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises displaying a projection of the roof feature at substantially the same time as receiving an indication of the roof feature of the building.

22. The non-transitory computer-readable storage medium of claim **16** wherein the method is performed iteratively, and the method further comprising:

providing an operator with an interactive model generation experience.

23. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises initiating displaying a projection of the roof feature on the first and second image by initiating display of a line on the first and second image.

24. The non-transitory computer-readable storage medium of claim **16** wherein the first image provides a perspective view of the roof of the building, and wherein the second image provides a substantially top plan view of the roof of the building.

25. The non-transitory computer-readable storage medium of claim **16** wherein the method further comprises:

modifying a three dimensional model of the roof based at least on the modification of the line drawing overlaid on the first aerial image.

26. A computer-implemented method in a roof estimate report system including a computer system and a memory coupled to the computer system, the method comprising:

changing, by the computer system of the roof estimate report system, a line in a first line drawing representing a feature of a roof that overlies a first aerial image of the roof;

changing, by the computer system of the roof estimate report system, a line in a second line drawing that corresponds to the same feature in the first line drawing that was changed, the change in the second line drawing being made by the computer system in response to the change that was made in the first line drawing; and

generating and outputting a roof estimate report using a report generation engine, wherein the roof estimate report includes numerical values for corresponding slope, area, or lengths of edges of at least some of a plurality of planar roof sections of the roof, wherein the generated roof estimate report is provided for repair and/or constructing the roof structure of the building.

27. The method of claim **26** wherein the roof feature is at least one of: a ridgeline of the roof, a valley of the roof, a rake edge of the roof, an eave of the roof, a hip ridge of the roof, and an edge of a section of the roof.

28. The method of claim **26** further comprising displaying the second line drawing after the first line drawing has been displayed.

29. The method of claim **26** wherein the step of changing, by the computer system of the roof estimate report system, a feature in the second line drawing overlying the second aerial image comprises:

changing the second line drawing at a time that is substantially concurrent to the time the changes are being made by the user in the first line drawing.

30. The method of claim **26** further comprising:

displaying the second line drawing overlying the second aerial image concurrently with displaying the first line drawing overlying the first aerial image of the roof.

31. The method of claim **26** further comprising:

displaying the second line drawing overlying the second aerial image at a later time, after the displaying of the first line drawing overlying the first aerial image of the roof on the display.

32. The method of claim **26** wherein the first image provides a substantially top plan view of the roof of the building, and the second image provides an oblique view of the roof of the building.

33. The method of claim **26** wherein the first image provides a first oblique view from a first compass bearing of the roof of the building, and the second image provides a second oblique view from a second compass bearing of the roof of the building.

34. The method of claim **26** further comprising:

displaying roof measurement information on the same display concurrently with the first line drawing being displayed.

35. The method of claim **34** wherein the step of displaying roof measurement information comprises:

displaying the roof measurement information in a location that overlays the first line drawing itself.

36. The method of claim **26** further comprising:

displaying a wire frame model of the roof in isolation from any images of the roof.

37. The method of claim **26** further comprising:

modifying a wire frame model of the roof based on input received from a user; and

making, by the computer system of the roof estimate report system, corresponding changes in a 3D model of the roof based on the changes made by the user to the wire frame model.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,135,737 B2
APPLICATION NO. : 14/450108
DATED : September 15, 2015
INVENTOR(S) : Chris Pershing

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Item (56):
"8,145,578 B2 3/2012 Pershing" should read --8,145,578 B2 3/2012 Pershing et al.--.

Item (56):
"Gaillard et al., :Automatic reconstruction of piecewise planar models from multiple views, CVPR99, vol. 2, 1999, pp. 559-565, 7 pages." should read --Baillard et al., "Automatic reconstruction of piecewise planar models from multiple views," CVPR99, vol. 2, 1999, pp. 559-565, 7 pages.--.

Colum 28, lines 7-9:
"displaying roof measurement information on the same display concurrently with the first line drawing being displayed." should read --displaying roof measurement information concurrently with the first line drawing being displayed.--.

Signed and Sealed this
Twenty-third Day of February, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office