

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN JIMUYIDA TECHNOLOGY CO., LTD.,

Petitioner,

v.

ARTEC EUROPE S.A.R.L.,

Patent Owner.

Case IPR2023-01148

U.S. Patent No. 7,768,656

PETITION FOR *INTER PARTES* REVIEW

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TABLE OF ABBREVIATIONS

'656	U.S. Patent No. 7,758,656
'656 FH	File History of U.S. Application No. 11/846,494
Tomasi	U.S. Pat. Appl. No. 2004/0005092
Vinther	WO 2007/059780
Vuylsteke	Vuylsteke and Oosterlinck, "Range Image Acquisition with a Single Binary-Encoded Light Pattern," <i>IEEE Transactions on Pattern Analysis and Machine Intelligence</i> , Vol. 12, No. 2, February 1990.
Claims	Claims 1-4, 6-15, and 17-22 ("Claims") of U.S. Patent No. 7,768,656
IPR	<i>Inter Partes</i> Review
Petitioner	Petitioner Shenzhen Jimuyida Technology Co., Ltd.
PO	Patent Owner Artec Europe S.A.R.L.
POSITA	Person of Ordinary Skill in the Art
PTAB	Patent Trial and Appeal Board
USPTO	United States Patent and Trademark Office

EXHIBIT LIST

EX1001	U.S. Patent No. 7,768,656
EX1002	File History of U.S. Application No. 11/846,494
EX1003	Declaration of Mohit Gupta in Support of Petition for Inter Partes Review of U.S. Patent No.
EX1004	U.S. Pat. Appl. No. 2004/0005092
EX1005	WO 2007/059780
EX1006	Vuylsteke and Oosterlinck, "Range Image Acquisition with a Single Binary-Encoded Light Pattern," <i>IEEE Transactions on Pattern Analysis and Machine Intelligence</i> , Vol. 12, No. 2, February 1990.
EX1007	Batlle, et al, "Recent Progress in Coded Structured Light as a Technique to Solve the Correspondence Problem: a Survey," <i>Pattern Recognition</i> , Vol. 31, No. 7, pp. 963-982
EX1008	Salvi, et al., "Pattern codification strategies in structured light systems," <i>Pattern Recognition</i> 37 (2004) 827 – 849
EX1009	Salvi, et al., "An overview of the advantages and constraints of coded pattern projection techniques for autonomous navigation," <i>Proceedings of the 1997 IEEE/RSJ International Conference on Intelligent Robot and Systems. Innovative Robotics for Real-World Applications. IROS '97</i> , Grenoble, France, 1997, pp. 1264-1271 vol.3

Pursuant to §§311-319 and §42.1, Shenzhen Jimuyida Technology Co., Ltd. (“Petitioner”) petitions for *inter partes* review of claims 1-4, 6-15, and 17-22 (“Claims”) of U.S. Patent No. 7,768,656 (EX1001), assigned to Artec Europe S.A.R.L. (“PO”). Petitioner requests review of the Claims, and judgment finding them unpatentable under §103. This Petition is supported by the Declaration of Mohit Gupta (EX1003), which describes the prior art’s scope and content at the time of the ’656. EX1003, ¶¶29-33, 44-63.

I. INTRODUCTION

The purported invention of the ‘656 is directed to a system and method for the 3D measurement of the shape of material objects. Specifically, the claims recite a system and method for projecting a structured light pattern onto a surface of an object, using a slide with a slide pattern, capturing an image of the structured light pattern reflected on the object, determining a measurement relating to the shape of the object using a triangulation algorithm, having a slide pattern that includes coded elements that can be assigned to groups, and defining virtual lines that pass through the groups of coded elements on the slide pattern and on the image of the object. EX1003, ¶¶34-35.

But such structured light systems and methods were well known in the art. EX1003 at ¶¶29-33. **Tomasi** (EX1004) discloses a system and method for

projecting a structured light pattern onto a surface of an object, using a slide with a slide pattern. EX1004, [0032]–[0036]. **Tomasi** also discloses capturing an image of the structured light pattern reflected on the object. *Id.*, [0038]. Further, **Tomasi** discloses determining a measurement relating to the shape of the object using a triangulation algorithm. *Id.*, [0039], [0081]. **Tomasi** also discloses a slide pattern that includes coded elements that can be assigned to groups. *Id.*, [0035], [0089]–[0091]. Finally, **Tomasi** discloses virtual lines that pass through the groups of coded elements on the slide pattern and on the image of the object. *Id.*, [0059]–[0061]. **Tomasi** qualifies as prior art at least under §102(b) because it was published on January 8, 2004, more than one year before the August 28, 2007 filing date of the ‘656.

Vinther (Ex. 1005) discloses a system and method for projecting a structured light pattern onto a surface of an object, using a slide with a slide pattern. EX1005, Abstract, 1:14-17, 6:31-7:2, 8:28-30. **Vinther** also discloses capturing an image of the structured light pattern reflected on the object. *Id.*, Abstract, 7:4-5, 8:5-6, 8:30-31. Further, **Vinther** discloses determining a measurement relating to the shape of the object using a triangulation algorithm. *Id.*, Abstract, 1:14-17, 8:30-32, 9:2-7. **Vinther** also discloses a slide pattern that includes coded elements that can be assigned to groups. *Id.*, Fig. 4, Fig. 5, 6:4-5, 7:18-27. Finally, **Vinther** discloses virtual lines that pass through the groups of

coded elements on the slide pattern and on the image of the object. *Id.*, Fig. 4, Fig. 5, Fig. 7, 7:18-35, 8:21-25. Vinther qualifies as prior art at least under §102(a) because it was published on May 31, 2007, which is prior to the August 28, 2007 filing date of the ‘656.

Vuylsteke (Ex. 1006) discloses a system and method for projecting a structured light pattern onto a surface of an object, using a slide with a slide pattern. EX1006, 148, 149, 153. **Vuylsteke** also discloses capturing an image of the structured light pattern reflected on the object. *Id.*, 153. Further, **Vuylsteke** discloses determining a measurement relating to the shape of the object using a triangulation algorithm. *Id.*, 148, 153. **Vuylsteke** also discloses a slide pattern that includes coded elements that can be assigned to groups. *Id.*, 148, 150. Finally, **Vuylsteke** discloses virtual lines that pass through the groups of coded elements on the slide pattern and on the image of the object. *Id.*, 148-151, 155. **Vuylsteke** qualifies as prior art at least under §102(b) because it was publicly available in or shortly after February 1990, more than one year before the August 28, 2007 filing date of the ‘656.

Claims 1-4, 6-15, and 17-22 are rendered obvious by combinations of **Tomasi**, **Vinther**, and **Vuylsteke** set forth herein. EX1003, ¶¶44-63. Petitioner requests that the Board institute trial and find the Claims unpatentable.

II. MANDATORY NOTICES

A. Real Parties-in-Interest

Petitioner Shenzhen Jimuyida Technology Co. Ltd. and Shenzhen Creality 3D Technology Co., Ltd. are the real parties-in-interest. No other party had access to or control over the present Petition, and no other party funded or participated in preparation of the present Petition.

B. Related Matters

The ‘656 is the subject of the following co-pending civil action:

Artec Europe S.A.R.L. v. Shenzhen Creality 3D Technology Co., Ltd., et al., No. 1:22-1676 (WFK)(VMS) (E.D.N.Y.).

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Petitioner consents to electronic service of documents to the email addresses of the counsel identified above.

III. PAYMENT OF FEES

The USPTO is authorized to charge any fees due during this proceeding to Deposit Account No. 603696.

IV. REQUIREMENTS FOR *INTER PARTES* REVIEW

A. Grounds for Standing

Pursuant to §42.104(a), Petitioner certifies that the '656 is available for IPR. Petitioner and any real parties-in-interest are not barred or estopped from requesting IPR challenging the claims on the grounds identified herein.

B. Identification of Challenge

Pursuant to §§42.104(b)-(b)(1), Petitioner requests IPR of claims 1-4, 6-15, and 17-22, and that the Board cancel the same as unpatentable.

Ground (§103)	Claims	References
1	1-4, 6-15, and 17-22	Tomasi in view of Vinther
2	1-4, 6-15, and 17-22	Tomasi in view of Vinther and further in view of Vuylsteke

V. ‘656 PATENT AND PROSECUTION HISTORY

A. ‘656

Challenged ‘656 claims 1-4, 6-15, and 17-22 generally recite a system and method for the 3D measurement of the shape of material objects. *See, e.g.*, EX1001, Abstract. An annotated version of claim 1 shows the claimed aspects of the system.

1. A system for the 3D measurement of the shape of a material object, comprising:

a light projector for projecting a structured light pattern onto a surface of said object, wherein said light projector comprises a light source, **a slide** with **a slide pattern located on a slide surface**, and a projector lens characterized by a projector lens vertex;

a device for capturing an image of said **structured light pattern** reflected on said object, wherein said device for capturing an image comprises a device lens characterized by a device lens vertex; and

a computing device for determining a measurement relating to the shape of said object using a triangulation algorithm based on a correspondence between points in said **slide pattern** and said image, and

wherein said **slide pattern** comprises a plurality of coded elements, where each of said **coded elements** is characterized by at least one parameter and, where said at least one parameter defines a spatial or temporal distribution of an amplitude or a wavelength of said structured light, and

wherein said **coded elements are assigned to one of at least first group or second group**, each of which first group and second group comprising at least two of said coded elements, and

wherein at least a first slide **virtual line** and a second slide **virtual line** are defined on said **slide** surface, where said first slide **virtual line** is defined by an intersection between said **slide** surface and a first plane passing through said **projector** lens vertex and through said **device** lens vertex, and said second slide **virtual line** is defined by an intersection between said **slide** surface and a second plane passing through said **projector** lens vertex and through said **device** lens vertex, and

wherein said **coded elements of said first group** are located along said first **virtual line** and said **coded elements of said second group** are located along said second **virtual line**.

An embodiment of claim 1 is shown in an annotated version of Figures 1 and 13 below.

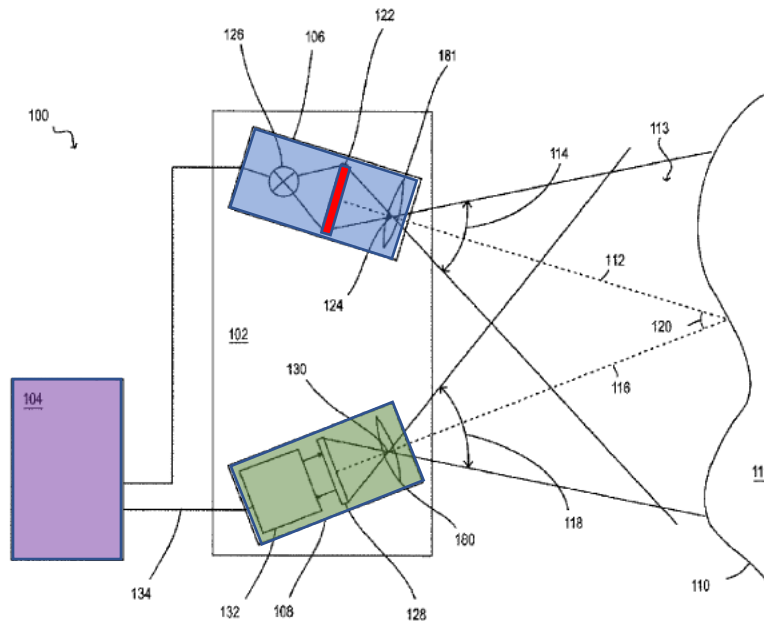


Fig. 1

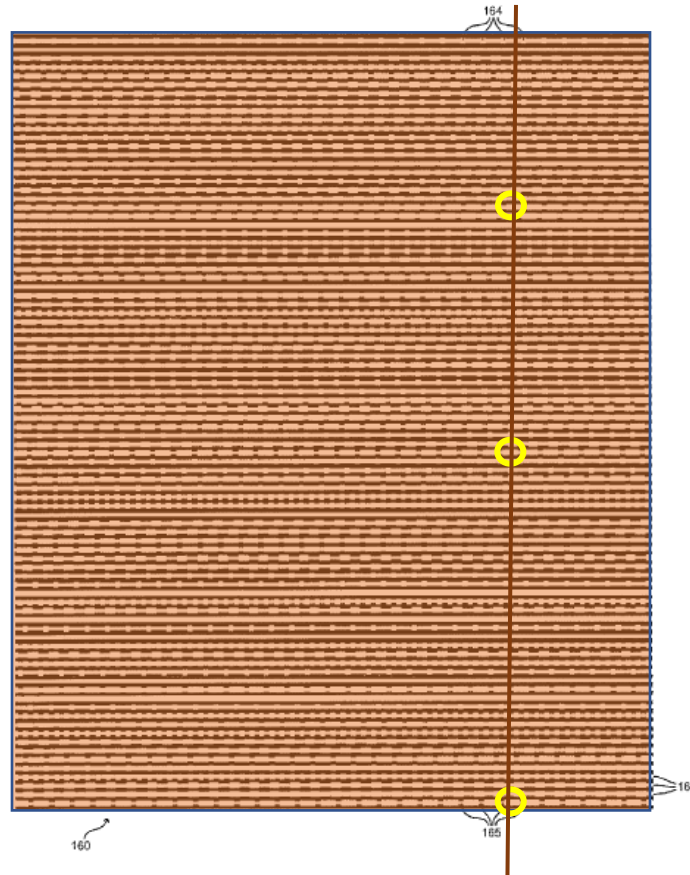


Fig. 13

The system includes a **projector** projecting a **structured light pattern** onto a surface of an object, using a **slide** with a **slide pattern**. *Id.*, Fig. 1, 3:4-29. The system also includes a **device for capturing an image** of the structured light pattern reflected on the object. *Id.*, Fig. 1, 3:30-48. The system includes a **computing device** for determining a measurement relating to the shape of the object using a triangulation algorithm. *Id.*, 3:49-56, 3:66-4:15. The system also requires that the slide pattern include **coded elements that can be assigned to groups**. *Id.*, 4:40-5:2, 5:11-7:17. In addition, **virtual lines** (or “meridians” as described in the specification) are defined that pass through the groups of coded

elements on the slide pattern and on the image of the object. *See, e.g., Id.*, 5:11-7:17. The virtual lines (or “meridians”) are inherent in the epipolar geometry that exists between the projector and the camera and are commonly referred to as “epipolar lines” in the literature. *Id.*, 5:11-19; EX1003, ¶¶29-32, 35, 43, 48, 49, 60.

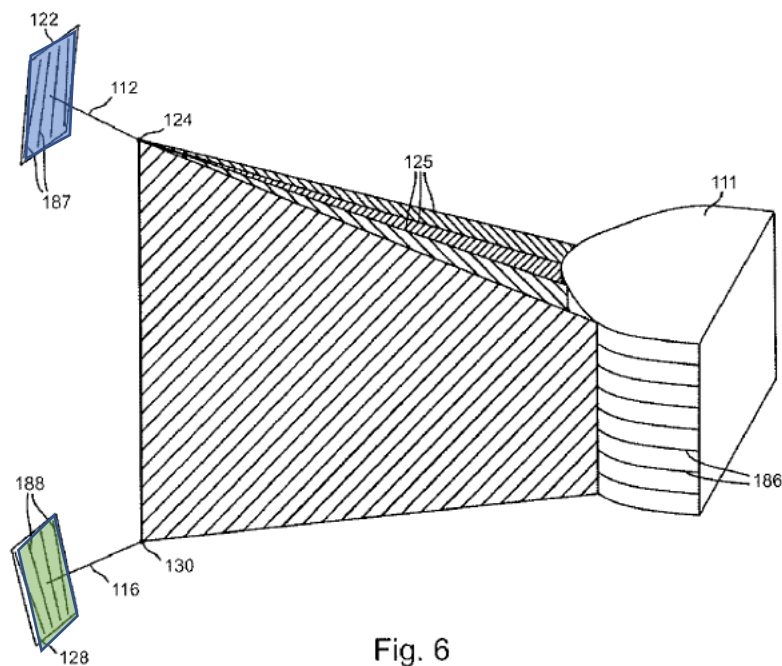


Fig. 6

In describing the nature of these meridians, the specification explains that “[i]n one or more embodiments, the system **100** and associated method for the 3D measurement of the shape of material objects uses the principle that, regardless of the position of the **projector 106** and the **camera 108** in relation to each other, it is possible to draw a straight line **187** through any point of the **slide 122**, such that, when the projected **pattern in the structured light 113** is projected on the

surface **110** of the object **111**, a corresponding straight line **188** exists in the image **140** captured by the **camera 108**, regardless of the shape of the surface **110** being captured. Any pair of such lines **187** and **188** forms a one-to-one correspondence, where such lines will be referred to as ‘**meridians**’ hereafter and, in particular, as ‘camera meridians **188**’ for the captured image by the camera **108** and as ‘projector meridians **187**’ for the projected structured light **113** from the projector **106**, as illustrated by way of example in FIG. 5. In one embodiment, the projector meridians **187** and camera meridians **188** are representative lines that can be represented on the surfaces of the slide **122** and the matrix radiation receiver **128**, but they are not actually part of the pattern that is projected onto the object **111** and captured by the camera **108**.” EX1001, 5:20-40.

B. Prosecution History

The application from which the ‘656 issued was filed as Ser. No. 11/846,494 on August 28, 2007. In an office action of July 1, 2009, the examiner rejected all claims as unpatentable. EX1002 at 106-115. Claims 1-3, 6-13, and 16-20 were rejected under 35 U.S.C. 102(b) as being anticipated by Geng (U.S. Pat. No. 6,937,348). *Id.*, 109-112. The examiner further found that claims 4-5 and 14-15 were obvious in view of Geng when combined with the knowledge of a person of ordinary skill in the art. *Id.*, 113-114.

In response to this office action, applicant amended the claims to add additional limitations primarily related to coded elements and virtual lines. *Id.*, 129-139. For example, claim 1 was amended as follows:

1. (Currently Amended) A system for the 3D measurement of the shape of a material object, comprising:

a light projector for projecting a structured light pattern onto a surface of an said object, wherein ~~the said~~ light projector ~~includes~~ comprises a light source, a slide with a slide pattern located on a slide surface, and a projector lens characterized by a projector lens vertex; for the projected structured light pattern;

~~an image detecting~~ a device for capturing an image of ~~the said~~ structured light pattern acting reflected on the surface of the said object, wherein ~~the image capturing said~~ device for capturing an image includes comprises a device lens characterized by a device lens vertex; for a field of view of the image detecting device; and

a computing device for determining a measurement relating to the ~~surface~~ shape of the said object using a triangulation algorithm based on a correspondence between points in said slide pattern and said image, ~~the projected structured light pattern and the captured image, and~~

~~wherein the structured light pattern includes at least two coded elements that lie within a plane passing through the vertices of the light projector and the image detecting device and a portion of the object being measured.~~

wherein said slide pattern comprises a plurality of coded elements, where each of said coded elements is characterized by at least one parameter having one of at least two values, and

wherein said coded elements are assigned to one of at least first group or second group, each of which first group and second group comprising at least two of said coded elements, and

wherein at least first slide virtual line and second slide virtual line are defined on said slide surface, where said first slide virtual line is defined by an intersection between said slide

surface and a first plane passing through said projector lens vertex and through said device lens vertex, and said second slide virtual line is defined by an intersection between said slide surface and a second plane passing through said projector lens vertex and through said device lens vertex, and

wherein said coded elements of said first group are located along said first virtual line and said coded elements of said second group are located along said second virtual line.

Id., 131-132.

In the remarks accompanying the amendment, applicant explicitly stated that the specific additional limitations were added to overcome the prior art. *Id.*, 137. Specifically, applicant stated that (1) Geng “fails to teach or suggest a system or method for 3D measurement of a material object where coded elements in the structured light patten are located along virtual lines that are defined by the intersections of the slide surface with a plurality of planes passing through the vertices of the light projector and the camera,” and (2) Geng “fails to teach or suggest a system or method for 3D measurement of a material object where coded elements are always found in the image along virtual lines that are defined by the same virtual planes that define the virtual lines along which the coded elements are located in the structured light pattern, *i.e.*, on the surface of the slide.” FH at 137. Applicant then asserted that the “pending claims, as amended, are not anticipated by Geng.” *Id.*, 138.

The applicant had an interview with the examiner on March 3, 2010, in which the parties reached an “[a]greement...with respect to the amendment overcoming the prior art of record.” *Id.*, 147. The claims, as explicitly amended to overcome the prior art of record, were issued on August 3, 2010.

VI. §325(d) AND §314(a) DISCRETION DOES NOT APPLY

A. §325(d)

Under *Advanced Bionics v. Med-El Elektromedizinische Gerate*, IPR2019-01469, Pap. 6, *8-9, the Board should not exercise §325(d) discretion.

The grounds raised by this Petition are not the same or substantially the same as the art and arguments raised during '656's prosecution. Tomasi, Vinther, and Vuylsteke were not considered during prosecution. As explained below, the Claims are obvious under the identified Grounds. *See* § IX.

B. §314(a)

The co-pending litigation also does not warrant exercising discretion under §314(a) based on the *Fintiv* factors.

1. Stay: Following institution, Petitioner intends to seek a stay of the Eastern District of New York case pending the outcome of this IPR. As such, this factor favors institution or is at worst neutral because the Board “will not attempt to predict” how the district court will proceed. *Sand Revolution II, LLC v. Continental Intermodal Group-Trucking LLC*, IPR2019-01393, Paper 24 at 7 (PTAB Jun. 16, 2020) (informative).

2. Proximity of Trial Date: No trial date is currently set. Based on the current median time of 64.1 months from filing to trial in the Eastern District of

New York,² even without a stay a trial would be expected in 2027, at least two years after conclusion of the instant proceeding. As such, this factor strongly counsels against denial. *See Google LLC v. Wildseed Mobile, LLC*, No. IPR2023-00247, Paper 29 at 22–23 (PTAB June 6, 2023) (finding this factor favors institution where district court trial would occur “about a year after any final written decision”).

3. Investment by the Court and Parties: To date, the parties have invested little to no resources in litigating the merits of the case, having only disputed preliminary injunctive relief and service. The case is in early discovery—claim construction is scheduled for February 21, 2024, fact discovery is set to close on July 17, 2024, and expert discovery is scheduled to close on October 18, 2024. *See Ability Opto-Elecs. Tech. Co., Ltd v. Largan Precision Co., Ltd.*, No. IPR2020-01339, Paper 10 at 20 (PTAB Feb. 22, 2021) (finding a similar schedule strongly weighed in favor of institution).

4. Overlap of Issues: After the final written decision, the same grounds of invalidity could not be presented in the litigation. 35 U.S.C. 315(e)(2).

² <https://www.uscourts.gov/statistics/table/na/federal-court-management-statistics/2023/03/31-1>.

5. Identity of Parties: Petitioner and Patent Owner are parties to the district court litigation. However, this is “far from an unusual circumstance” in IPR proceedings. *Sand Revolution II* at 12.

6. Other Factors, Including Merits: The merits of this Petition are compelling as shown herein. Notably, none of the prior art Petitioner relies upon was considered during prosecution. As such, assuming the Board reaches the merits factor, it strongly weighs in favor of institution.

VII. LEVEL OF ORDINARY SKILL

For purposes of this Petition only, Petitioner assumes the Claims are entitled to the ’656’s filing date, 8/28/2007. EX1003, ¶39.

A person of ordinary skill in the art (“POSITA”) as of the claimed priority date of the ’656 would have had a bachelor’s degree in computer systems, computer science, or the equivalent thereof, and at least two years of experience with 3D scanning or related technology. *Id.*, ¶41. More education can supplement practical experience, and vice-versa. *Id.*

VIII. CLAIM CONSTRUCTION

Claim terms subject to IPR are construed using *Phillips v. AWH Corp.*, 415 F.3d 1303, 1313 (Fed. Cir. 2005). §42.100(b). Only terms necessary to resolve the controversy need construction. *Nidec Motor Corp. v. Zhongshan Broad Ocean*

Motor, 868 F.3d 1013, 1017 (Fed. Cir. 2017). Because the prior art asserted herein discloses embodiments within the Claims’ indisputable scope, the Board need not construe the Claims’ outer bounds. All claim terms should generally be construed according to their plain and ordinary meaning. EX1003, ¶43. All of the claims use the phrase “virtual line,” which is used for the first time in the claims and does not appear anywhere else in the specification or file history. Nevertheless, in examining the specification, the term “virtual line” as properly construed refers to the “meridians” described in the patent specification, which are themselves commonly referred to as the epipolar lines inherent in the geometry of a structured light 3D imaging system including a projector and a camera. *Id.*

IX. GROUNDS OF UNPATENTABILITY

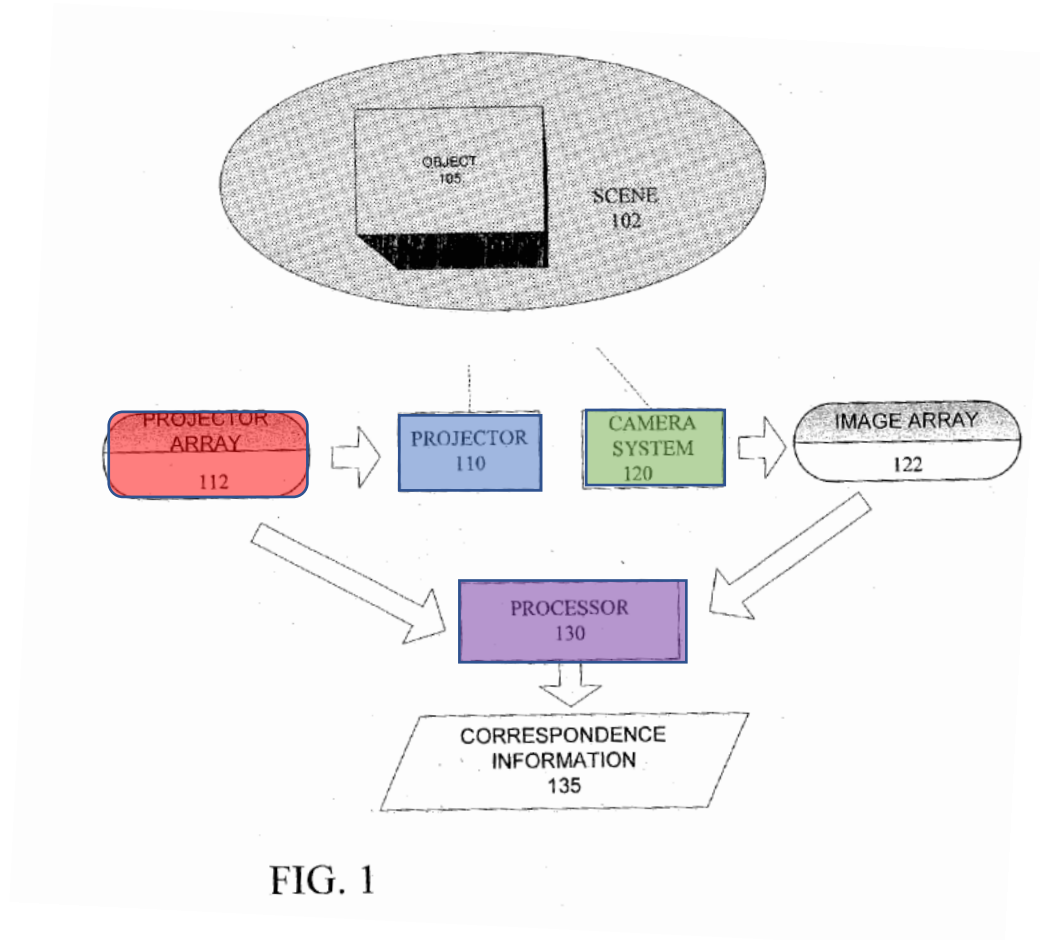
A. Ground 1: Tomasi in View of Vinther

Tomasi in view of **Vinther** renders obvious claims 1-3, 6-13, and 16-20; any purported differences between this art and the claims would have been obvious to a POSITA. EX1003, ¶44.

1. Overview of Tomasi

Tomasi teaches “an image correspondence system [that] may be used to optically observe an object and determine three dimensional features, characteristics and other information of the object.” EX1004, [0032]. Tomasi

explains that “[t]he components of the system include a **projector** 10, a **camera** 120 and a **processor** 130.” *Id.*, [0033].



Id., Fig. 1.

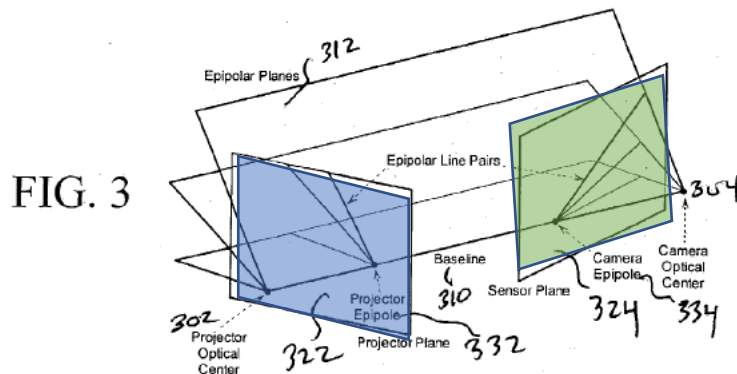
Tomasi then explains that “[t]he projector 110 projects an **array 112 of coded light onto the scene 102. Coded light refers to light that is structured or patterned so that it can be represented as propagating from projector 110 as an array with identifiable array elements.** The projector 110 includes a light-emitting source and some mechanism that causes light projecting from it to be

coded. For example, projector 110 may include a bulb and a **slide** having a **pattern**. When the light passes through the **slide**, the contents of the slide code the light. In one embodiment, light is projected as a grid when directed at the scene 102, so that grid points are then identifiable on the scene 102. The light may be coded so that the select grid points are identifiable, or otherwise distinguishable from each other.” *Id.*, [0034]. In addition, the coded elements “may be assigned a size from a set of two or more sizes.” *Id.*, [0035].

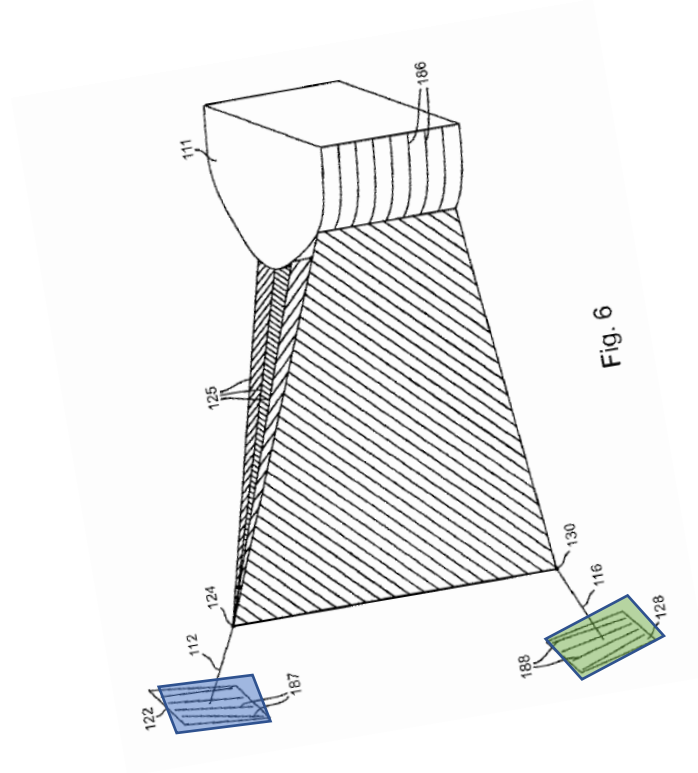
Tomasi also explains that these coded elements can be assigned to groups: “a group of contiguous symbols in the image contains, so to speak, its own address: the arrangement of symbols in the group is unique to that particular group in that row of the projected array, and it cannot be confused with any other group. Correspondence between projected and imaged group can therefore be established.” *Id.*, [0092].

In addition, Tomasi explains that epipolar geometry can be used to define virtual epipolar lines. “Because of the epipolar geometry (which is described in more detail with FIG. 3), no ambiguity is possible between epipolar lines: the epipolar line to which an image point belongs determines the corresponding array epipolar line uniquely. The position of an array point within a given epipolar line in the image, on the other hand, depends on the geometry of the surface being imaged.” *Id.*, [0057]. Tomasi further explains that “[t]he projector optical center

302 of the projector 110 (FIG. 1) and the camera optical center 304 determine a line in space that is called the baseline 310. Consider the set of all planes that contain the baseline 310. These are called the epipolar planes 312 of the camera-projector pair. Some of the epipolar planes 312 intersect the image area of the projector 110, as well as the rectangle of the camera 120. For instance, if a standard slide projector and a CMOS camera are used, some of the epipolar planes 312 will intersect the slide, and the same planes intersect the surface of the CMOS camera. The lines formed by these intersections are called epipolar lines in computer vision. The two lines formed by the intersection of a single epipolar plane with the projector plane 322 and camera plane 324 form an epipolar line pair.” *Id.*, [0059].



Id., Fig. 3.



Compare, EX1001, Fig. 6.

Tomasi explains that symbols (or coded elements) are grouped along a given epipolar line for the purpose of aiding correspondence between projected and imaged structured light patterns. “The importance of the epipolar geometry for embodiments described herein is that any point on a given epipolar line in the projector plane 322 must map onto the corresponding epipolar line in the camera plane 324. Thus, when the projector 110 projects an array of symbols onto scene 102, the points in a given row of the array can only move within their epipolar line in the image: no point can ever leave its epipolar line.” *Id.*, [0061].

2. Overview of Vinther and Motivation to Modify Tomasi with Vinther's Teachings

In the same field of endeavor, Vinther discloses “a system and method for creating a three-dimensional model of a surface using coded structured light.”

EX1005, 1:3-4.

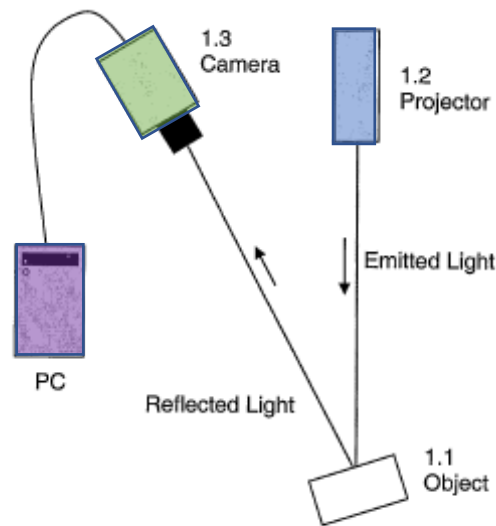


Fig. 1

Id., Fig. 1.

Vinther discloses that the system includes a projector, camera, and computer. “The present invention is a system and method for creating a three-dimensional model of a surface comprising a light source 1.2 that projects a pattern of continuous line segments onto the surface, wherein each line segment is coded with a unique pattern along the line segment, a detector 1.3 that records an image of the surface with said projecting pattern, and a computer for

transforming said image to a three-dimensional model of the surface utilizing said projected pattern.” *Id.*, Abstract. Vinther discloses that “[t]he projector could be a simple slide projector where the slide contains the coded lines (see Figure 8), it could be a LCD/DMD projector or the pattern could be generated by one or more laser.” *Id.*, 8:28-30. Vinther discloses that the system includes a camera for capturing images. “The detector according to the present invention may be any suitable detector, such as a digital camera.” *Id.*, 7:4-5. Vinther discloses that the computer uses a triangulation algorithm. “When the relative positions of the internal parameters of the projector and the camera are known then the three-dimensional shape of the illuminated part of the object can be computed using triangulation. This is known as structured light scanning and described in the prior art.” *Id.*, 1:14-17.

In addition, Vinther discloses a structured light pattern that includes coded elements. “Unique pattern: A predetermined recognizable modulation of a line segment identifying said line segment either relative to any other line segment projected by the light source or relative to the proximal line segments. A unique pattern may be repeated in line segments belonging to the same line.” *Id.*, 4:11-14. “To be able to distinguish the projected lines in a recorded image the invention proposes using a coding along the lines as e.g. varying line width or intensity. This

could e.g. be a **binary coding** as shown in Figure 4 or a frequency and/ phase coding as shown in Figure 5.” *Id.*, 7: 18-21.

Vinther then discloses that the coded elements can be grouped along virtual lines. “Determining the linear transformation of the coding and other system parameters needed for obtaining absolute object measurements can be done by recoding a number of calibration images with an object of known dimensions. To support the calibration process a number of horizontal lines [5.3] [7.1] can be inserted in the source image.” *Id.* 8:21-25. These **virtual (calibration) lines** pass through a **group of coded elements**.

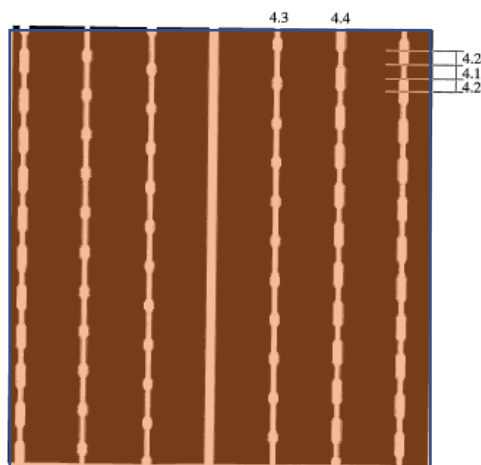


Fig. 4

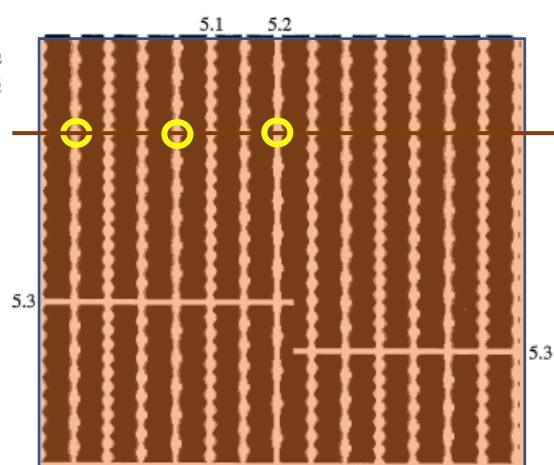


Fig. 5

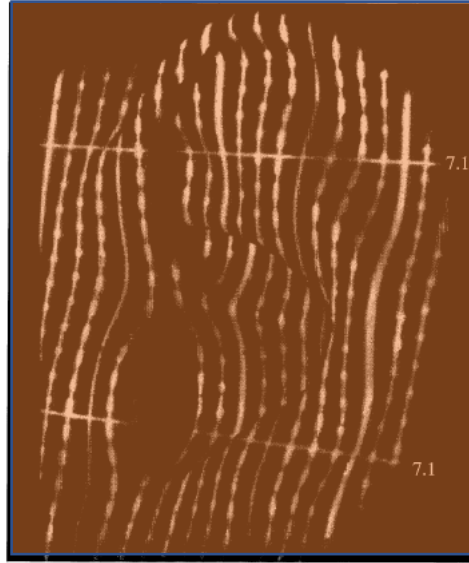


Fig. 7

Id., Figs. 4, 5, and 7.

Tomasi and **Vinther** are analogous prior art and in the same field as the ‘656—three-dimensional modeling of an object surface—and pertinent to the alleged problems identified in the ‘656 of correspondence between points in the captured image and the slide pattern. *See, e.g.*, EX1001, 4:40-5:19, 5:55-6:2.

In light of the above teachings, a POSITA would have had a motivation and a reasonable expectation of success in modifying **Tomasi** with **Vinther’s** teachings by using, for example, **Vinther’s** specific structured light pattern, which is very similar to the one disclosed in the ‘656.

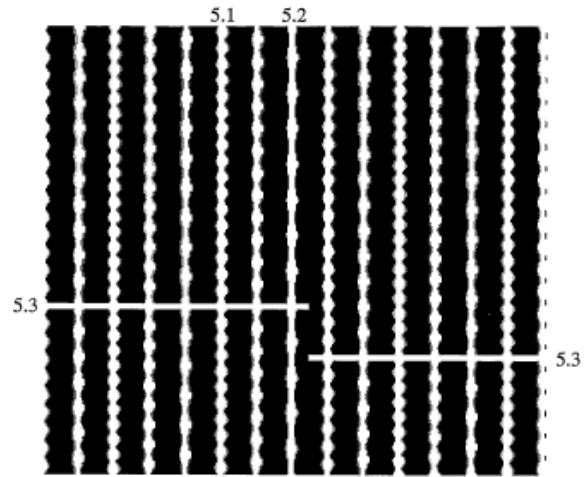


Fig. 5

EX1005, Fig. 5.

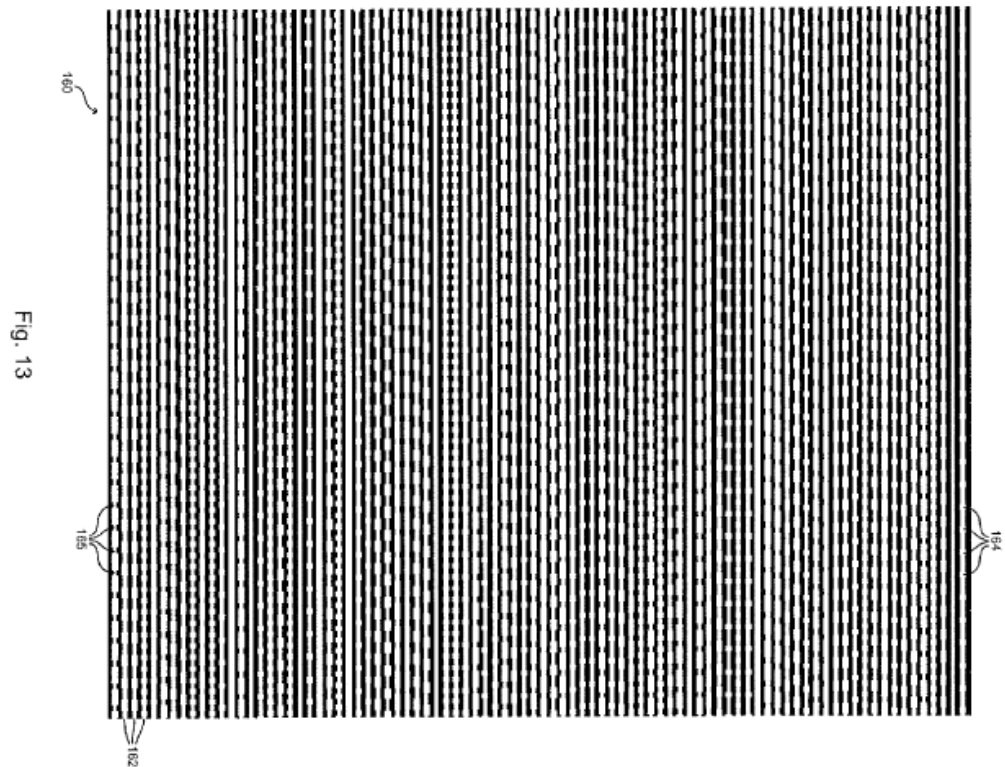


Fig. 13

Compare, EX1001, Fig. 13.

Tomasi already teaches that the coded elements “may be assigned a size from a set of two or more sizes.” EX1004, [0035]. Consistent with that, **Vinther** teaches that “[t]o be able to distinguish the projected lines in a recorded image the invention proposes using a coding along the lines as e.g. varying line width or intensity.” EX1005, 7: 18-19. Indeed, it was well understood to a POSITA at the time of the invention to look to other 3D scanning implementations for guidance in how to implement such a system. There is significant technical survey literature in the field of 3D scanning dedicated to reviewing and analyzing various methods and systems for solving issues in 3D scanning. *See, e.g.*, EX1007; EX1008; EX1009. Modifying **Tomasi** with **Vinther’s** teachings would have been a straightforward application of those teachings in a manner that advantageously improves the efficiency of a 3D scanning system. EX1003, ¶44-56.

3. Claim Chart

‘656 Claim	Tomasi in view of Vinther
1. [1.PREAMBLE] A system for the 3D measurement of the shape of a material object, comprising:	Tomasi discloses this claim element. Tomasi discloses constructing a topographical map of three-dimensional scenes. [0003] (“Three-dimensional sensor systems are increasingly being used in a wide-array of applications. In one general application, a three-dimensional sensor system is used to determine the shape and/or features of an object positioned in a scene of the sensor system's view.”)

'656 Claim	Tomasi in view of Vinther
	<i>See also</i>, [0004], [0022], [0032], [0125]. Vinther also discloses this claim element. Vinther discloses using structured light to create a three-dimensional model of a surface. Abstract (“The present invention is a system and method for creating a three-dimensional model of a surface comprising a light source 1.2 that projects a pattern of continuous line segments onto the surface, wherein each line segment is coded with a unique pattern along the line segment, a detector 1.3 that records an image of the surface with said projecting pattern, and a computer for transforming said image to a three-dimensional model of the surface utilizing said projected pattern.”) <i>See also</i>, 1:11-18, 4:8-9, 6:34-7:2, 9:9-19.
[1.A] a light projector for projecting a structured light pattern onto a surface of said object, wherein said light projector comprises a light source, a slide with a slide pattern located on a slide surface, and a projector lens characterized by a projector lens vertex;	Tomasi discloses this claim element. Tomasi discloses a projector that projects a structured light pattern onto the surface of an object, including a bulb (light source), a slide having a pattern, and a projector optical center (lens vertex).

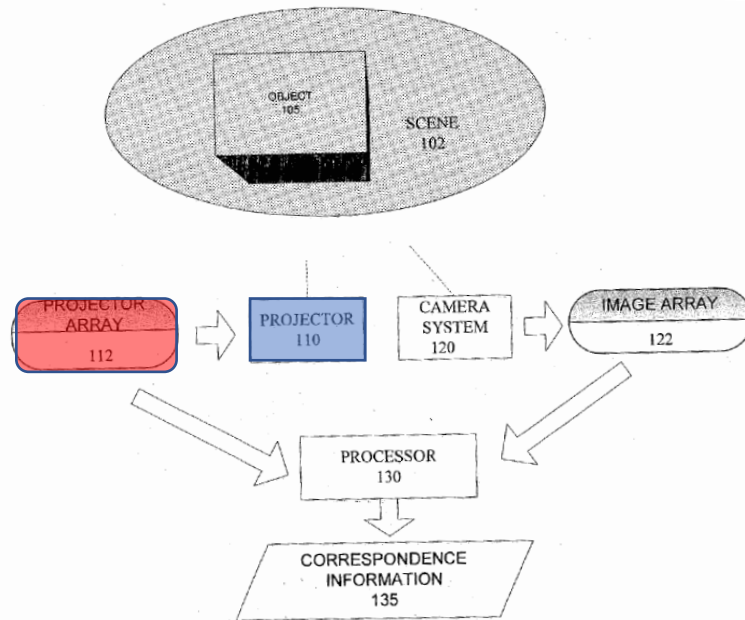
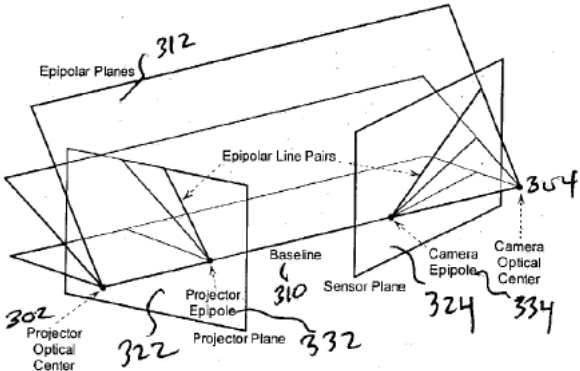


FIG. 1

[0004] (“**Structured-light** methods have had success because of their superior accuracy and resolution.”)

[0034] (“The **projector 110 projects an array 112 of coded light onto the scene 102**. Coded light refers to light that is structured or patterned so that it can be represented as propagating from projector 110 as an array with identifiable array elements. The projector 110 includes a light-emitting source and some mechanism that causes light projecting from it to be coded. For example, projector 110 may include **a bulb and a slide having a pattern**. When the light passes through the slide, the contents of the slide code the light. In one embodiment, light is projected as a grid when directed at the scene 102, so that grid points are then identifiable on the scene 102. The light may be coded so that the select grid points are identifiable, or otherwise distinguishable from each other. . . . In another embodiment, the projection array 112 may correspond to a tangible medium, such as a **slide**, that includes a grid pattern for producing the coded light structure.”)

'656 Claim	Tomasi in view of Vinther
	[0036] (“The projector 110 may be similar to a slide projector in applications where electrical power is readily available. The coding may be provided by a slide containing a pattern, which in turn causes the projected light to have a pattern. In this case, the projection array 112 may correspond to a specific pattern formed on the slide.”) FIG. 3  [0059] (“FIG. 3 is a diagram illustrating the concept of epipolar geometry, as it applies to embodiments of the invention. The projector optical center 302 of the projector 110 (FIG. 1) and the camera optical center 304 determine a line in space that is called the baseline 310.”) <i>See also, [0007], [0033], [0038], [0061], [0075], [0089], claim 35.</i> Vinther also discloses this claim element. Vinther discloses a projector that projects a structured light pattern onto the surface of an object, including a light source, a slide having a pattern, and a projector optical center (lens vertex).

'656 Claim	Tomasi in view of Vinther
	The diagram illustrates a structured light scanning setup. A Personal Computer (PC) is connected via a cable to a Camera (labeled 1.3) and a Projector (labeled 1.2). The Projector emits a beam of light (labeled 'Emitted Light') onto an Object (labeled 1.1). The light reflects off the object and is captured by the Camera (labeled 'Reflected Light'). The entire setup is labeled 'Fig. 1'. Fig. 1 6:31-7:2 (“The light source used according to the present invention may be any suitable light source. Accordingly, any structured light may be used, such as the light source in a conventional projector, or a laser light, or a blitz light. The light source may emit visible light, near-visible or invisible light as is suitable for the image and the surface. In particular for creating a three-dimensional model of a surface of a human being or an animal it may be preferred to use invisible light.”) 1:14-17 (“When the relative positions of the internal parameters of the projector and the camera are known then the three-dimensional shape of the illuminated part of the object can be computed using triangulation. This is known as structured light scanning and described in the prior art.”) 2:1-2 (“... different angles of refraction in the camera and projector lenses. . . .”) 2:31-32 (“... (a) a light source that projects a pattern of continuous line segments onto the surface, wherein each

'656 Claim	Tomasi in view of Vinther
	line segment is coded with a unique pattern along the line segment") 8:28-30 ("The projector could be a simple slide projector where the slide contains the coded lines (see Figure 8), it could be a LCD/DMD projector or the pattern could be generated by one or more lasers.")
[1.B] a device for capturing an image of said structured light pattern reflected on said object, wherein said device for capturing an image comprises a device lens characterized by a device lens vertex; and	Tomasi discloses this claim element. Tomasi discloses a camera for capturing images, including a lens having an optical center (lens vertex). <pre> graph TD PA([PROJECTOR ARRAY 112]) --> P[PROJECTOR 110] P --> S([SCENE 102]) S --> CS[CAMERA SYSTEM 120] CS --> IA([IMAGE ARRAY 122]) PA --> PR[PROCESSOR 130] IA --> PR PR --> CI[/CORRESPONDENCE INFORMATION 135/] </pre> FIG. 1 [0038] ("The camera 120 captures an image of the scene 102. When coded light is cast on the scene 102, the resulting image has a representation of the projection array 112. The image of the projection array 112 is at least partially captured in image array 122. The camera 120 may include a lens (not shown) and a frame grabber which obtains data corresponding to image array 122. In one embodiment, the image array is a digital

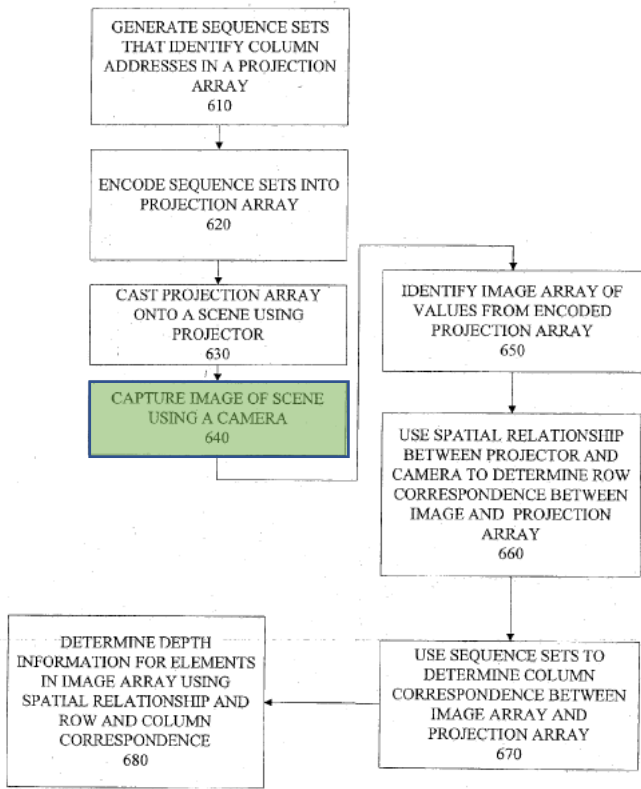
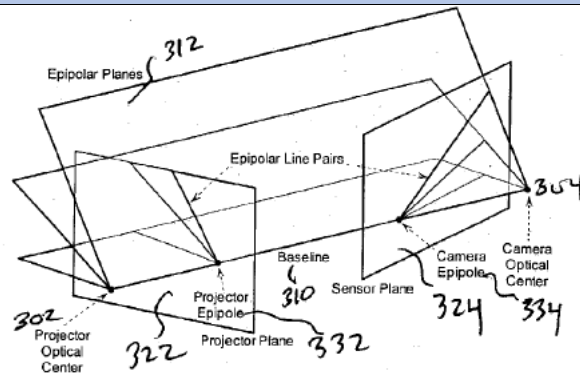
'656 Claim	Tomasi in view of Vinther
	representation of the coded light on the scene 102 and the object 105. The depth of field of the camera should be sufficient to distinguish the different types of code in the light coding emitted from projector 110. . . . Enough depth of field in turn requires a sufficient amount of light for a camera lens with a relatively small aperture. . . . In one embodiment, the camera 120 is of a charged couple device (CCD) or complimentary metal-oxide semiconductor (CMOS) design.”)  <pre> graph TD 610[GENERATE SEQUENCE SETS THAT IDENTIFY COLUMN ADDRESSES IN A PROJECTION ARRAY 610] --> 620[ENCODE SEQUENCE SETS INTO PROJECTION ARRAY 620] 620 --> 630[CAST PROJECTION ARRAY ONTO A SCENE USING PROJECTOR 630] 630 --> 640[CAPTURE IMAGE OF SCENE USING A CAMERA 640] 640 --> 650[IDENTIFY IMAGE ARRAY OF VALUES FROM ENCODED PROJECTION ARRAY 650] 650 --> 660[USE SPATIAL RELATIONSHIP BETWEEN PROJECTOR AND CAMERA TO DETERMINE ROW CORRESPONDENCE BETWEEN IMAGE AND PROJECTION ARRAY 660] 660 --> 670[USE SEQUENCE SETS TO DETERMINE COLUMN CORRESPONDENCE BETWEEN IMAGE ARRAY AND PROJECTION ARRAY 670] 670 --> 680[DETERMINE DEPTH INFORMATION FOR ELEMENTS IN IMAGE ARRAY USING SPATIAL RELATIONSHIP AND ROW AND COLUMN CORRESPONDENCE 680] </pre> FIG. 6

FIG. 3



[0059] (see [1.A])

See also, [0007], [0024], [0033], [0077], claim 35.

Vinther also discloses this claim element.

Vinther discloses a camera for capturing images, comprising a lens with a focal point (lens vertex).

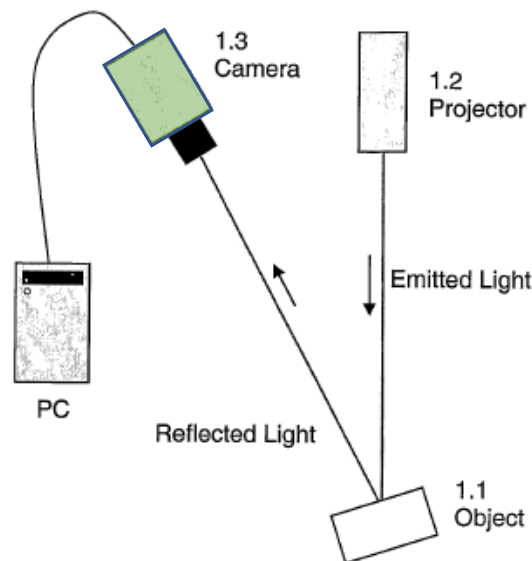


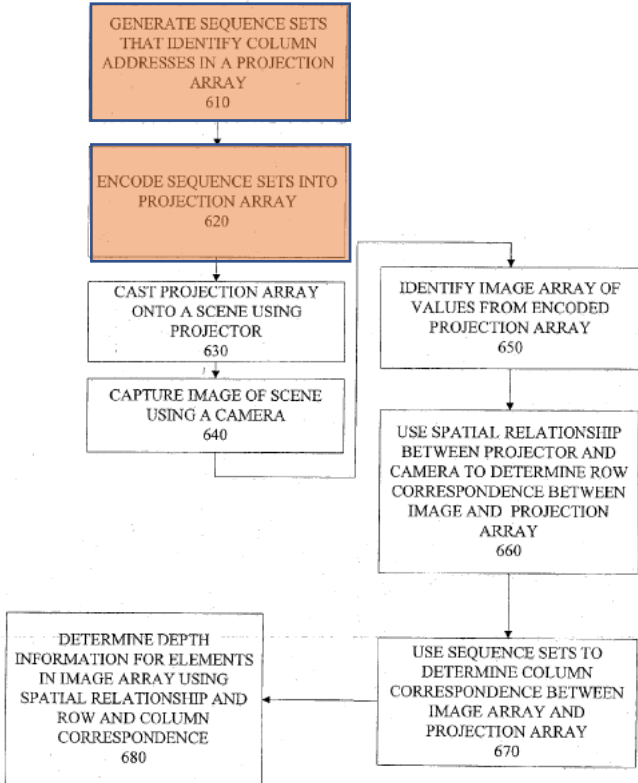
Fig. 1

Abstract (see [1.PREAMBLE])

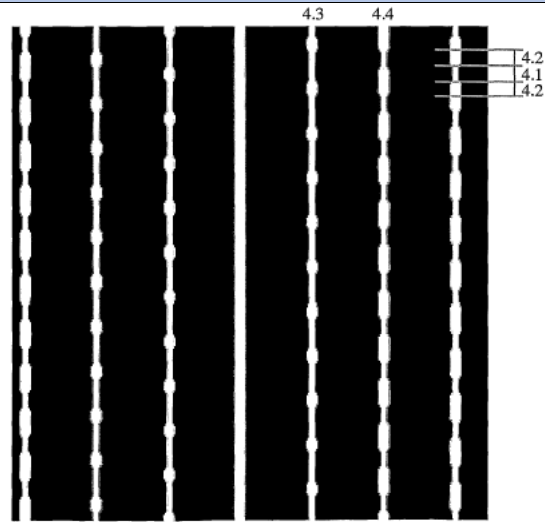
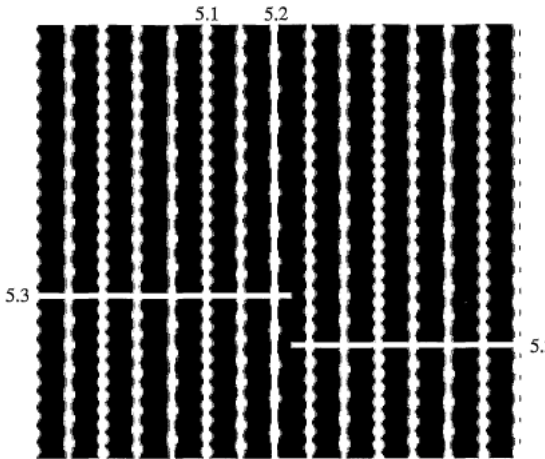
7:4-5 (“The detector according to the present invention may be any suitable detector, such as a **digital camera**.”)

'656 Claim	Tomasi in view of Vinther
	8:5-6 (“This is true if the coded lines in the light source image in [1.2] are perpendicular to the axis between the focal line of the camera and the projector.”) 8:30-31 (“A TV-camera or digital camera (typically CCD or CMOS based) connected to a computer supplies the images.”) See also, 1:9-18, 1:35-2:3, claim 1.
[1.C] a computing device for determining a measurement relating to the shape of said object using a triangulation algorithm based on a correspondence between points in said slide pattern and said image, and	Tomasi discloses this claim element. Tomasi discloses computing a 3-D surface using a triangulation algorithm based on computing correspondences between points in the slide pattern and the image. [0039] (“Embodiments of the invention provide that processor 135 receives data representing image array 122 and projection array 112. Using techniques such as described in FIGS. 2 and 3, the processor 130 determines a correspondence between an element of the image array 122 and an element of the projection array 112. This correspondence is referred to as correspondence information 135.”) FIG. 5 [0081] (“In step 680, depth information is determined for elements in the image array 112 using the row and column correspondence determined in step 660 and step 670. In

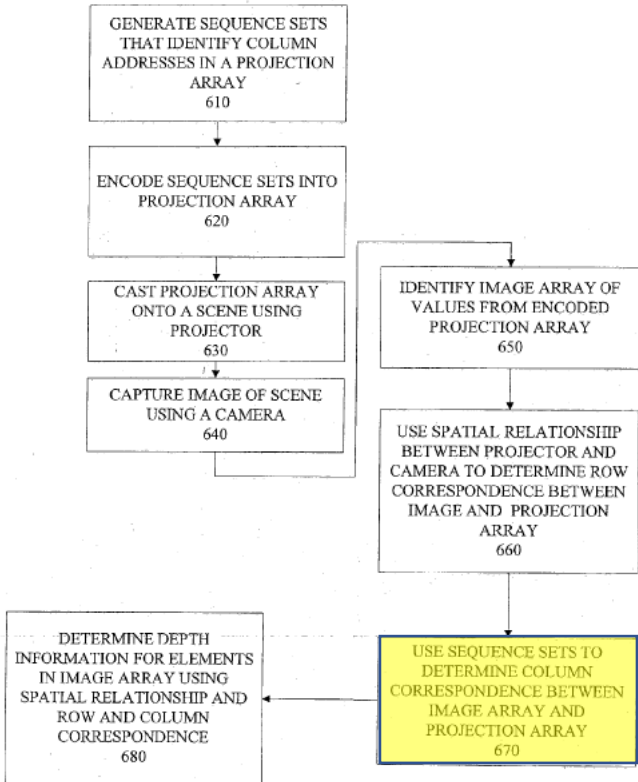
'656 Claim	Tomasi in view of Vinther
	one embodiment, triangulation techniques such as described in FIG. 5 may be employed to determine how far a region on the surface represented by an element of the image array 122 is from the camera 120. This distance may be determined by determining how the column coordinate of the image element differs from its corresponding projector element, as well as knowing a spatial relationship between the camera 120 and the projector 110.”) <i>See also</i>, [0007], [0008], [0025], [0026], [0092]. Vinther also discloses this claim element. Vinther discloses computing 3-D coordinates using a triangulation algorithm based on computing correspondences between points in the slide pattern and the image. Abstract (<i>see</i> [1.PREAMBLE]) 1:14-17 (<i>see</i> [1.A]) 8:30-32 (“A TV-camera or digital camera (typically CCD or CMOS based) connected to a computer supplies the images. A number of algorithms for detecting lines in digital images are known in the prior art.”) 9:2-7 (“Once the lines are found they must be identified based on the coding as described above, and at last the three dimensional position of each pixel along each line can be computed using triangulation. Algorithms for connecting the points in space to a continuous surface are also described in the prior art. One way to do this is to connect neighbouring points with triangles as shown in Figure 9.”) <i>See also</i>, 3:1-2, 10:10-11.

'656 Claim	Tomasi in view of Vinther
[1.D] wherein said slide pattern comprises a plurality of coded elements, where each of said coded elements is characterized by at least one parameter and, where said at least one parameter defines a spatial or temporal distribution of an amplitude or a wavelength of said structured light, and	Tomasi discloses this claim element. Tomasi discloses a spatially distributed binary coded pattern comprising a plurality of grid points (coded elements). Each grid point is characterized by parameters including color defining a spatial distribution of wavelength, and/or size defining a spatial distribution of amplitude.  <pre> graph TD 610[GENERATE SEQUENCE SETS THAT IDENTIFY COLUMN ADDRESSES IN A PROJECTION ARRAY 610] --> 620[ENCODE SEQUENCE SETS INTO PROJECTION ARRAY 620] 620 --> 630[CAST PROJECTION ARRAY ONTO A SCENE USING PROJECTOR 630] 630 --> 640[CAPTURE IMAGE OF SCENE USING A CAMERA 640] 620 --> 650[IDENTIFY IMAGE ARRAY OF VALUES FROM ENCODED PROJECTION ARRAY 650] 650 --> 660[USE SPATIAL RELATIONSHIP BETWEEN PROJECTOR AND CAMERA TO DETERMINE ROW CORRESPONDENCE BETWEEN IMAGE AND PROJECTION ARRAY 660] 660 --> 670[USE SEQUENCE SETS TO DETERMINE COLUMN CORRESPONDENCE BETWEEN IMAGE ARRAY AND PROJECTION ARRAY 670] 640 --> 680[DETERMINE DEPTH INFORMATION FOR ELEMENTS IN IMAGE ARRAY USING SPATIAL RELATIONSHIP AND ROW AND COLUMN CORRESPONDENCE 680] 670 --> 680 </pre> FIG. 6 [0035] (“In one embodiment, the scheme for coding the light provides that each grid point is assigned a value, and a sequence of values from a set of congruent grid points identifies one individual grid point amongst the set. The particular manner in which light can be coded to reflect Sequence values for individual elements of an array is described in with FIGS. 7-12. In addition, the manner in which the light may be coded may vary. In one

'656 Claim	Tomasi in view of Vinther
	embodiment, the light is structured so that each grid point is assigned one symbol or geometric identifier from a set of two or more such identifiers. In another embodiment, grid points are colored to have one color from a set of two or more colors. Still further, grid points may be assigned a size from a set of two or more sizes. Other variations and identifiers are possible. In the end, the coding scheme selected assigns values to specific characteristics of light propagated from the projector 110. In a binary scheme, two or three values (0,1 and parity) are utilized.”) [0089] (“Coding the light from the projector 110 requires assigning an optically distinguishable attribute to each element of the projection array 112. For purpose of description, each element of the projection array 112 is said to be assigned a symbol representing a binary value.”) [0090] (“To address these difficulties, the array of symbols projected onto the scene 102 may be endowed with two properties. The first property ensures that examination of a small pattern from the array allows computing the position or address of the pattern within the array itself. This may be achieved by designing the symbols in the array so that groups of symbols within the same row in the array are never repeated.”) <i>See also, [0006], [0021], [0024], [0038], [0075], [0076], [0091], [0103], claims 1, 12, 16, 35.</i> Vinther also discloses this claim element. Vinther discloses a binary coded pattern comprising lines (coded elements). Each line is characterized by parameters including line width or intensity defining a spatial distribution of amplitude.

'656 Claim	Tomasi in view of Vinther
	 Fig. 4  Fig. 5 6:4-5 (“As described below in greater detail, the continuous line segments may be coded using a binary or n-ary sequence or by changing frequency and/or phase.”) 7:18-27 (“To be able to distinguish the projected lines in a recorded image the invention proposes using coding along the lines as e.g. varying line width or intensity. This could e.g. be a binary coding as shown in Figure 4 or a frequency and/ phase coding as shown in Figure 5.

'656 Claim	Tomasi in view of Vinther
	With a binary coding one could define the length of a bit [4.1]/[4.2] to be e.g. 1/100 of the total height of the projected image and a thin line [4.1] as 0 and a wide line [4.2] as 1. This would give the line [4.3] the code 010010010 ... (top-down) and the line [4.4] the code 110110110 With just a short segment of a line, in this case at least corresponding to the length of 3 bits, one is able to identify the segment.”) <i>See also, claim 9.</i>
[1.E] wherein said coded elements are assigned to one of at least first group or second group, each of which first group and second group comprising at least two of said coded elements, and	Tomasi discloses this claim element. Tomasi discloses groups of grid points (coded elements), each group containing at least two coded elements. [0061] (“The importance of the epipolar geometry for embodiments described herein is that any point on a given epipolar line in the projector plane 322 must map onto the corresponding epipolar line in the camera plane 324. Thus, when the projector 110 projects an array of symbols onto scene 102, the points in a given row of the array can only move within their epipolar line in the image: no point can ever leave its epipolar line.”) [0092] (“If these two properties are satisfied, a group of contiguous symbols in the image contains, so to speak, its own address: the arrangement of symbols in the group is unique to that particular group in that row of the projected array, and it cannot be confused with any other group. Correspondence between projected and imaged group can therefore be established. Standard triangulation, such as described in FIG. 5, may then be applied between individual points within the group of symbols in order to compute a high-resolution depth map of the scene 102.”)

'656 Claim	Tomasi in view of Vinther
	 <pre> graph TD 610[GENERATE SEQUENCE SETS THAT IDENTIFY COLUMN ADDRESSES IN A PROJECTION ARRAY 610] --> 620[ENCODE SEQUENCE SETS INTO PROJECTION ARRAY 620] 620 --> 630[CAST PROJECTION ARRAY ONTO A SCENE USING PROJECTOR 630] 630 --> 640[CAPTURE IMAGE OF SCENE USING A CAMERA 640] 640 --> 650[IDENTIFY IMAGE ARRAY OF VALUES FROM ENCODED PROJECTION ARRAY 650] 650 --> 660[USE SPATIAL RELATIONSHIP BETWEEN PROJECTOR AND CAMERA TO DETERMINE ROW CORRESPONDENCE BETWEEN IMAGE AND PROJECTION ARRAY 660] 660 --> 670[USE SEQUENCE SETS TO DETERMINE COLUMN CORRESPONDENCE BETWEEN IMAGE ARRAY AND PROJECTION ARRAY 670] 670 --> 680[DETERMINE DEPTH INFORMATION FOR ELEMENTS IN IMAGE ARRAY USING SPATIAL RELATIONSHIP AND ROW AND COLUMN CORRESPONDENCE 680] </pre> FIG. 6 <i>See also, [0074], [0075], [0090].</i> Vinther also discloses this claim element. Vinther discloses groups of lines (coded elements), each group containing at least two coded elements.

'656 Claim

Tomasi in view of Vinther

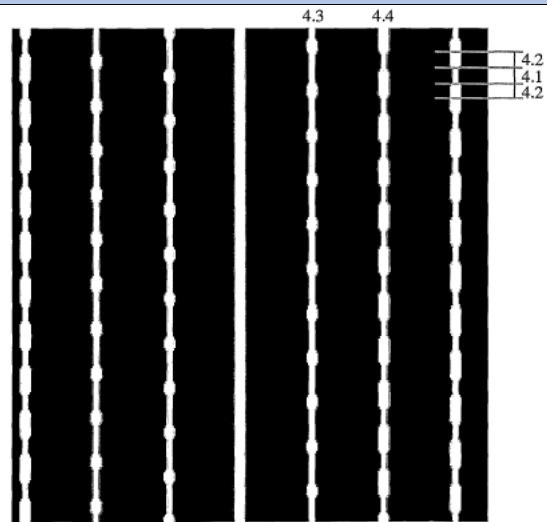


Fig. 4

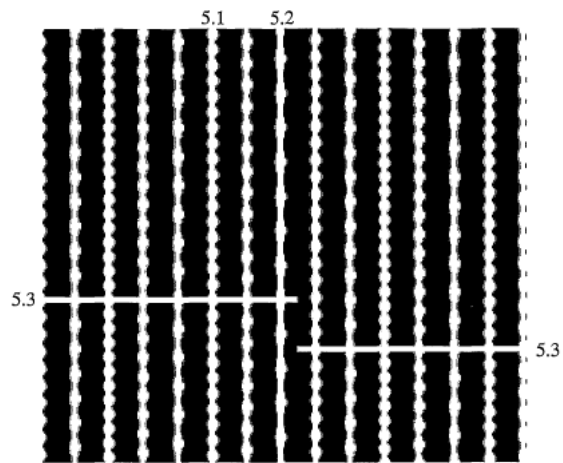
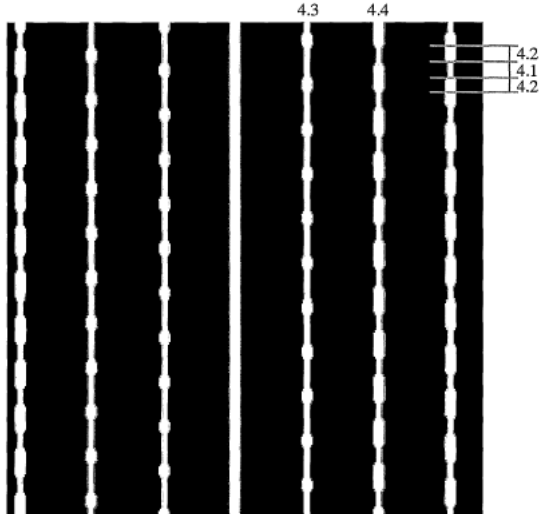
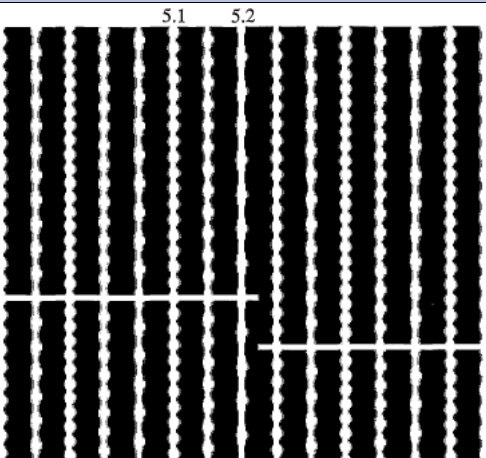
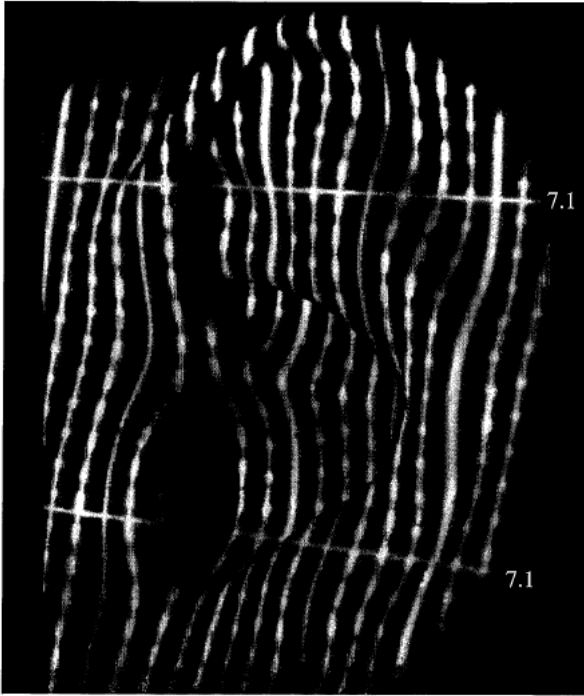


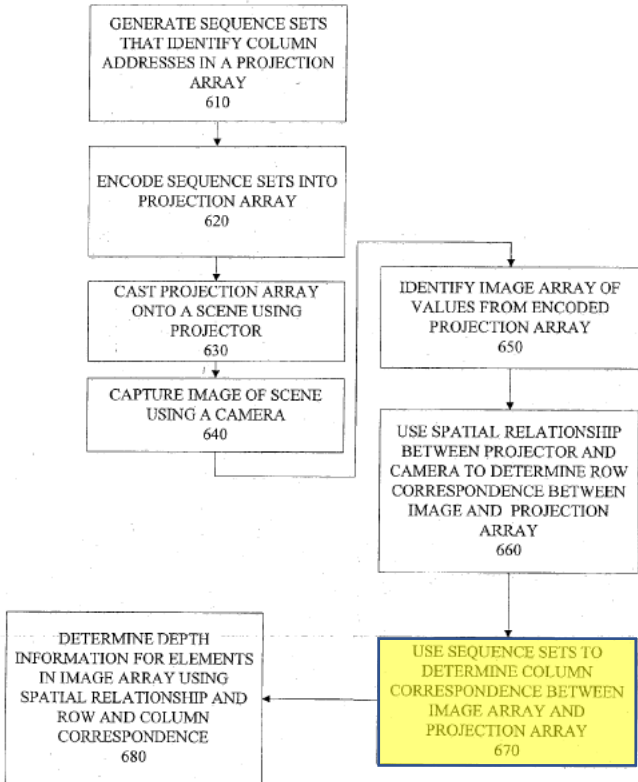
Fig. 5

'656 Claim	Tomasi in view of Vinther
	Fig. 7 7:18-35 (“To be able to distinguish the projected lines in a recorded image the invention proposes using a coding along the lines as e.g. varying line width or intensity. This could e.g. be a binary coding as shown in Figure 4 or a frequency and/ phase coding as shown in Figure 5. With a binary coding one could define the length of a bit [4.1]/[4.2] to be e.g. 1/100 of the total height of the projected image and a thin line [4.1] as 0 and a wide line [4.2] as 1. This would give the line [4.3] the code 010010010 ... (top-down) and the line [4.4] the code 110110110 With just a short segment of a line, in this case at least corresponding to the length of 3 bits, one is able to identify the segment. In another embodiment of the invention the line width could change as a sinusoidal function of the distance from the top with different frequency and phase for each line. In the example in Figure 5 one can see that the line [5.1] has a higher frequency than the line [5.2]. A Fourier transform of a band of pixel values along a line segment in the recorded image will give the frequency that identifies the line. The length of a line segment should preferably be at

'656 Claim	Tomasi in view of Vinther
	least as long as the cycle of the sinusoidal for certain identification.”) 8:21-25 (“Determining the linear transformation of the coding and other system parameters needed for obtaining absolute object measurements can be done by recoding a number of calibration images with an object of known dimensions. To support the calibration process a number of horizontal lines [5.3] [7.1] can be inserted in the source image.”)
[1.F] wherein at least a first slide virtual line and a second slide virtual line are defined on said slide surface, where said first slide virtual line is defined by an intersection between said slide surface and a first plane passing through said projector lens vertex and through said device lens vertex, and said second slide virtual line is defined by an intersection between said slide surface and a second plane passing through said projector lens vertex and through said device lens vertex, and	Tomasi discloses this claim element. Tomasi discloses multiple epipolar planes passing through the projector lens vertex and the device lens vertex. Further, Tomasi discloses epipolar line pairs related to each of the projector optical center (lens vertex) and the camera optical center (lens vertex) that exist along the same epipolar plane. Tomasi also discloses that multiple epipolar planes and epipolar line pairs define virtual lines on the slide surface. FIG. 3 [0059] (<i>see</i> [1.A]) [0060] (“The importance of the epipolar geometry for embodiments described herein is that any point on a given epipolar line in the projector plane 322 must map onto the corresponding epipolar line in the camera plane 324. Thus, when the projector 110 projects an array of symbols onto scene 102, the points in a given row of the

'656 Claim	Tomasi in view of Vinther
	array can only move within their epipolar line in the image: no point can ever leave its epipolar line.”) <i>See also</i>, [0061], [0074], [0075], [0090], [0092]. Vinther also discloses this claim element. Vinther discloses using multiple virtual lines to resolve the correspondence between points of the slide pattern and points in the captured image. Vinther discloses defining virtual lines on the slide pattern. These virtual lines relate to planes inherent in the epipolar geometry (called epipolar planes) that exists between the projector and the camera.  The diagram shows a series of vertical black bars (slide pattern) with white dashed lines. Labels 4.3 and 4.4 are above the bars. On the right, a legend shows three horizontal lines labeled 4.2, 4.1, and 4.2 from top to bottom, corresponding to the dashed lines in the pattern. Fig. 4

'656 Claim	Tomasi in view of Vinther
	 Fig. 5  Fig. 7 7:18-35 (<i>see</i> [1.E]) 8:21-25 (<i>see</i> [1.E])
[1.G] wherein said coded elements of	Tomasi discloses this claim element.

'656 Claim	Tomasi in view of Vinther
said first group are located along said first virtual line and said coded elements of said second group are located along said second virtual line.	Tomasi discloses groups of coded elements located along each of the epipolar lines that are inherent in the epipolar geometry. [0060] (<i>see</i> [1.F]) [0092] (<i>see</i> [1.E])  <pre> graph TD 610[GENERATE SEQUENCE SETS THAT IDENTIFY COLUMN ADDRESSES IN A PROJECTION ARRAY 610] --> 620[ENCODE SEQUENCE SETS INTO PROJECTION ARRAY 620] 620 --> 630[CAST PROJECTION ARRAY ONTO A SCENE USING PROJECTOR 630] 630 --> 640[CAPTURE IMAGE OF SCENE USING A CAMERA 640] 640 --> 650[IDENTIFY IMAGE ARRAY OF VALUES FROM ENCODED PROJECTION ARRAY 650] 650 --> 660[USE SPATIAL RELATIONSHIP BETWEEN PROJECTOR AND CAMERA TO DETERMINE ROW CORRESPONDENCE BETWEEN IMAGE AND PROJECTION ARRAY 660] 660 --> 670[USE SEQUENCE SETS TO DETERMINE COLUMN CORRESPONDENCE BETWEEN IMAGE ARRAY AND PROJECTION ARRAY 670] 670 --> 680[DETERMINE DEPTH INFORMATION FOR ELEMENTS IN IMAGE ARRAY USING SPATIAL RELATIONSHIP AND ROW AND COLUMN CORRESPONDENCE 680] </pre> FIG. 6 <i>See also</i>, [0059], [0074], [0075], [0090], [0092]. Vinther also discloses this claim element. Vinther discloses multiple virtual lines passing through groups of coded elements.

'656 Claim

Tomasi in view of Vinther

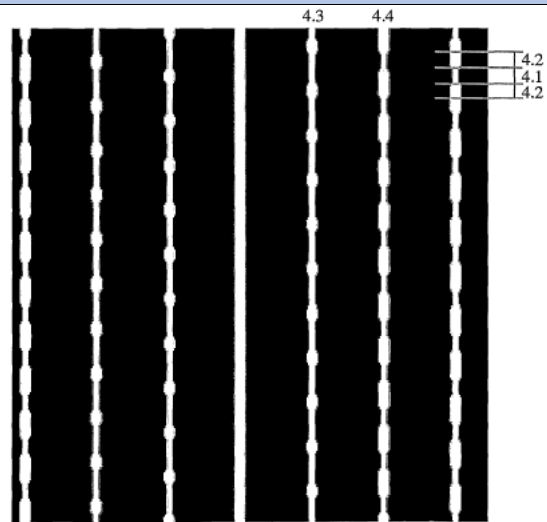


Fig. 4

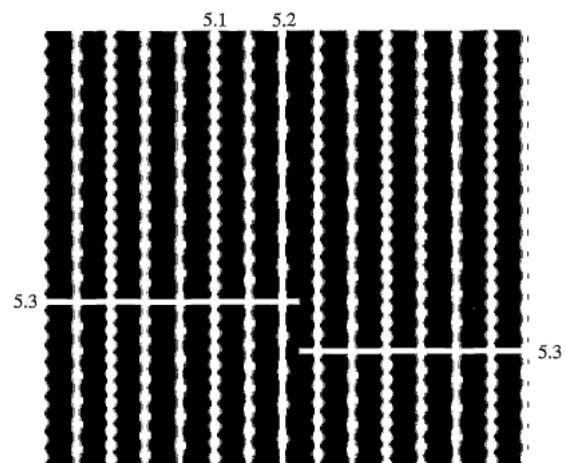


Fig. 5

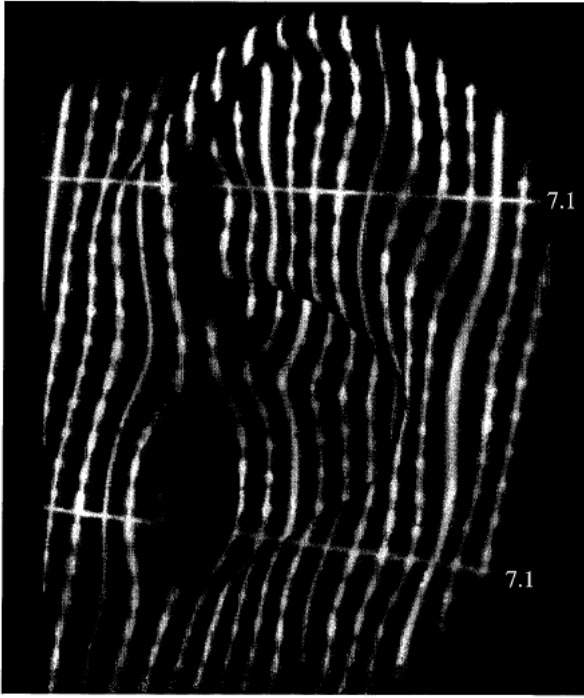
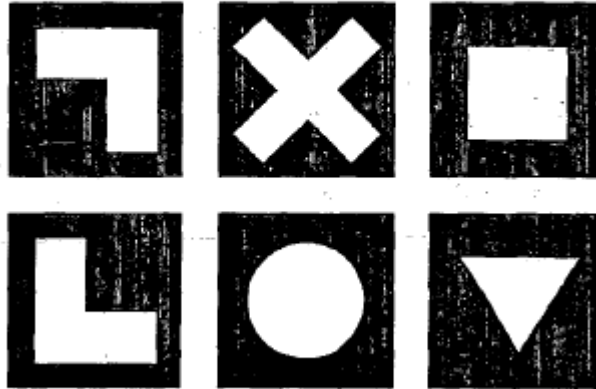
'656 Claim	Tomasi in view of Vinther
	 Fig. 7 7:18-35 (<i>see</i> [1.E]) 8:21-25 (<i>see</i> [1.E])
2. The system of claim 1, wherein each of said coded elements having at least three points that do not lie on a straight line.	Tomasi discloses this claim element. Tomasi discloses that coded elements consist of varying symbols having vertices that do not lie on a straight line, <i>e.g.</i> square, triangle, etc.

FIG. 10

[0035] (*see* [1.D])

[0089] (*see* [1.D])

Vinther also discloses this claim element.

Vinther discloses that coded elements consist of squares or rectangles of light. The vertices of a square or rectangle do not lie on a straight line.

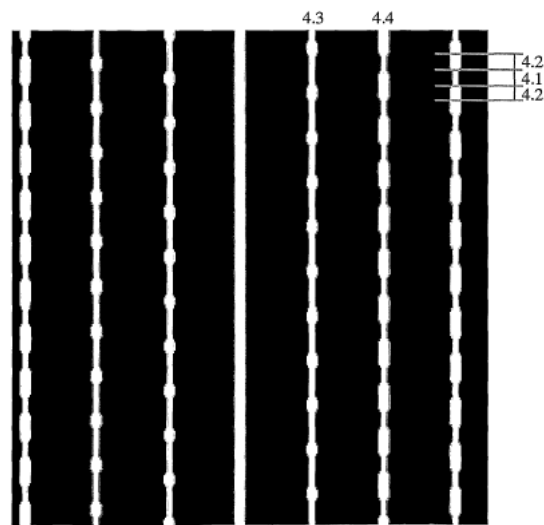
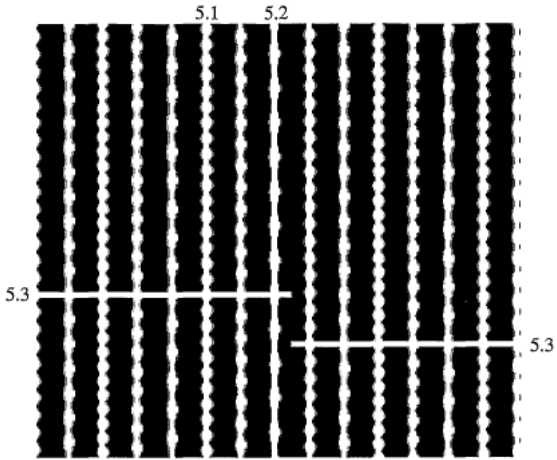
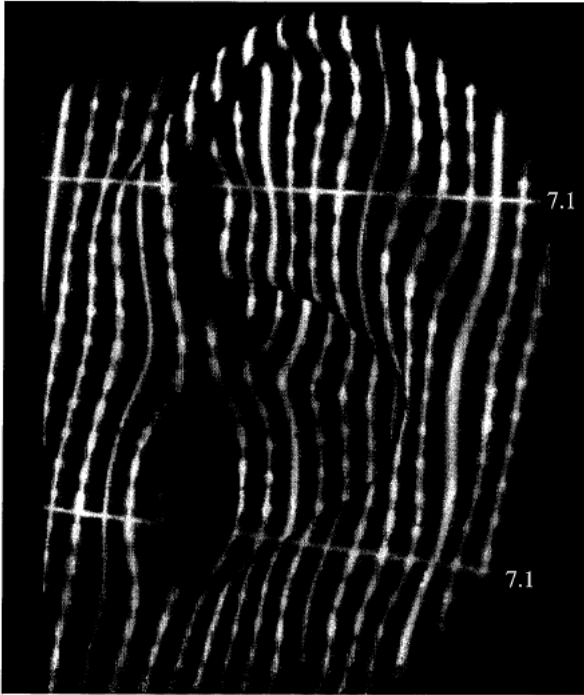


Fig. 4

'656 Claim	Tomasi in view of Vinther
	 Fig. 5  Fig. 7 7:18-35 (<i>see</i> [1.E])
3. The system of claim 1, wherein at	Tomasi discloses this claim element.

'656 Claim	Tomasi in view of Vinther
least first object virtual line and second object virtual line are defined on the surface of said object, where said first object virtual line is defined by an intersection between said surface of said object and said first plane and where said second object virtual line is defined by an intersection between said surface of said object and said second plane.	Tomasi discloses that there are multiple epipolar planes intersecting an object and thereby defining virtual lines on an object. FIG. 3 [0059] (<i>see</i> [1.A]) [0060] (<i>see</i> [1.F]) <i>See also</i>, [0061], [0074], [0075], [0090], [0092]. Vinther also discloses this claim element. Vinther also discloses that virtual lines can be defined on the surface of the object. These virtual lines relate to epipolar planes inherent in the epipolar geometry that exists between the projector lens vertex and the camera lens vertex. These light planes are projected onto an object.

'656 Claim

Tomasi in view of Vinther

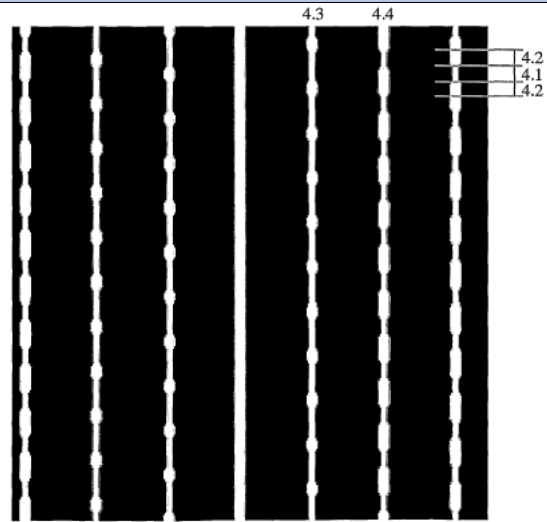


Fig. 4

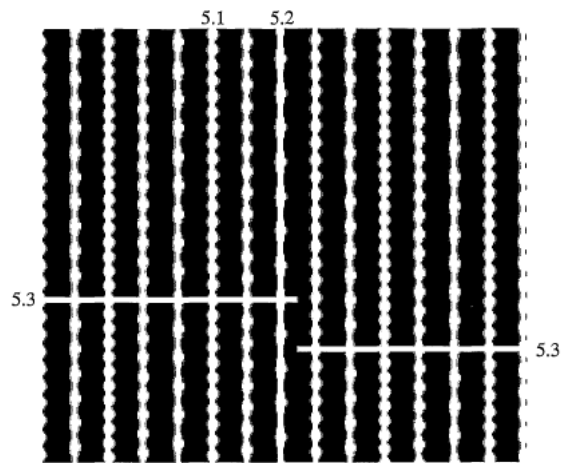
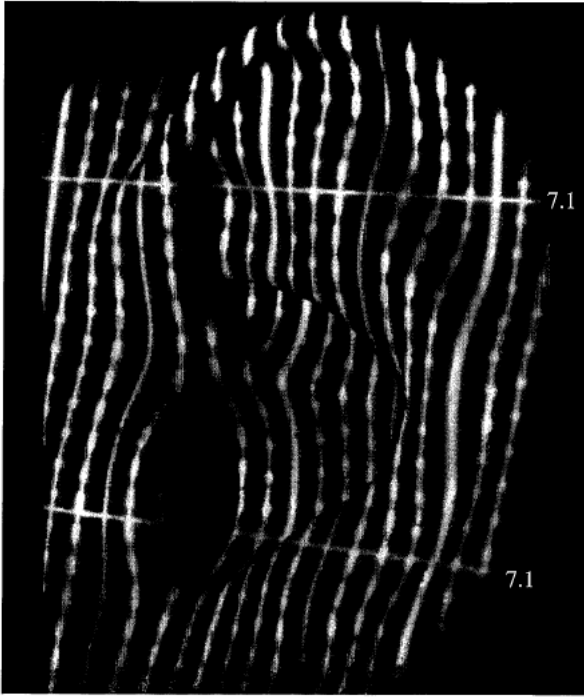
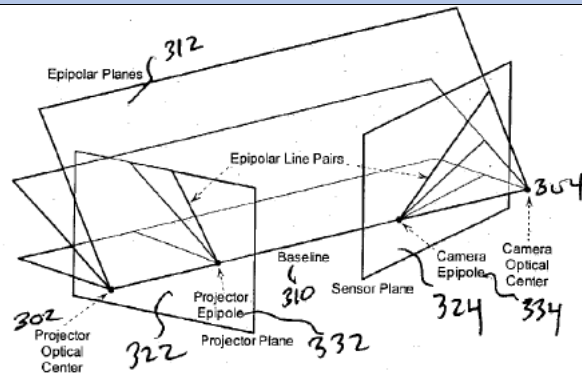


Fig. 5

'656 Claim	Tomasi in view of Vinther
	 Fig. 7 7:18-35 (<i>see</i> [1.E]) 8:21-25 (<i>see</i> [1.E])
4. The system of claim 1, wherein the light projector is further characterized by a central optical axis, further wherein the light projector and the device for capturing an image are arranged such that a line extending between the projector vertex and the device vertex is	Tomasi discloses this claim element. Tomasi discloses that a line extending between the optical center of the projector and the optical center of the camera could be perpendicular to the central optical axis.

'656 Claim	Tomasi in view of Vinther
perpendicular to the central optical axis of the light projector.	FIG. 1 [0033] (“The components of such a system include a projector 10, a camera 120 and a processor 130. The projector 110 and the camera 120 are each aligned in a direction of a scene 102, where an object 105 is provided. In an embodiment, a known spatial or geometric relationship exists between the camera 120 and the projector 110. Specifically, the camera 120 and the projector 110 may be placed in a side-by-side orientation with respect to the scene 102. To simplify computations, an optical center of the projector 110 and an optical center of the camera 120 may have parallel optical axes.”)

FIG. 3



[0059] (see [1.A])

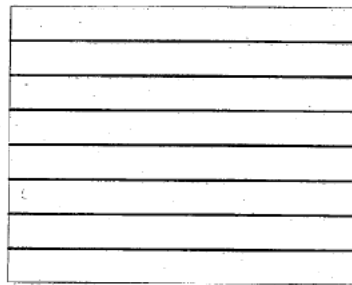


FIG. 4A

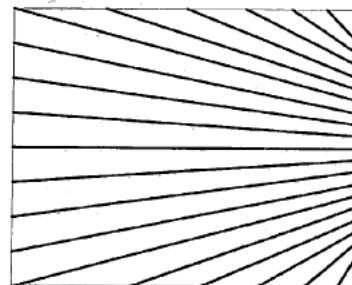


FIG. 4B

[0060] (see [1.F])

See also, [0061].

Vinther also discloses this claim element.

Vinther discloses that a line extending between the optical center of the projector and the optical center of the camera could be perpendicular to the central optical axis.

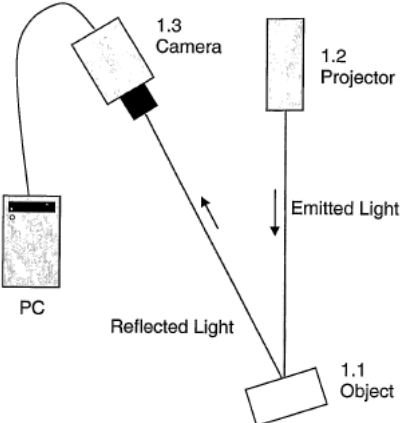
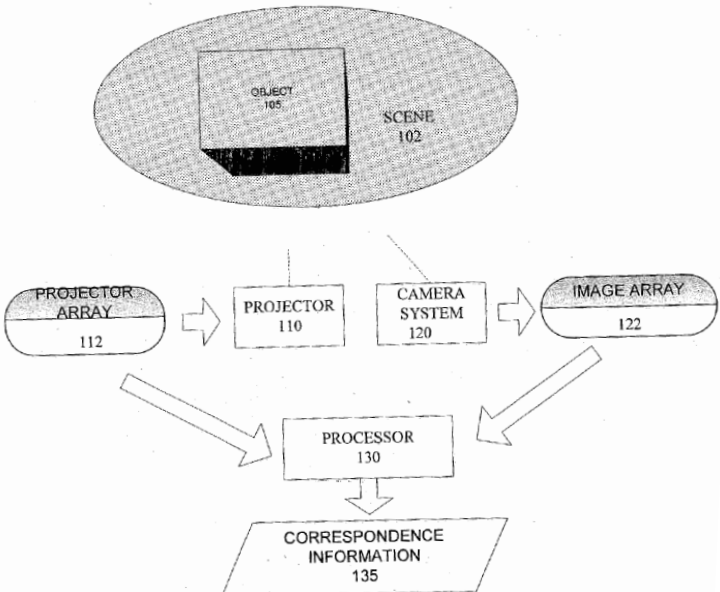
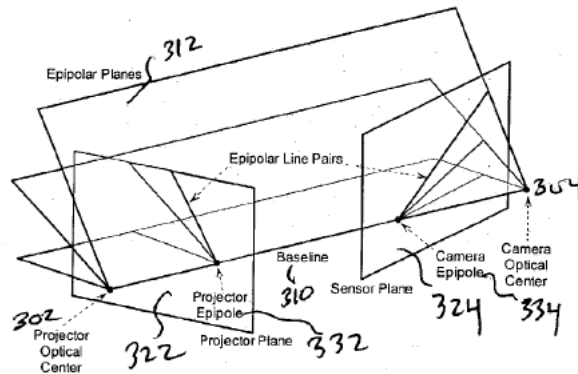
'656 Claim	Tomasi in view of Vinther
	 Fig. 1
6. The system of claim 1, wherein the light projector is characterized by a projector central optical axis and wherein the device for capturing an image is characterized by a device central optical axis, further wherein the light projector and the device for capturing an image are arranged such that a line extending between the projector vertex and the device vertex is not perpendicular to either the projector optical axis or the device optical axis.	Tomasi discloses this claim element. Tomasi discloses that a line extending between the optical center of the projector and the optical center of the camera may not be perpendicular to the camera optical axis.  FIG. 1 [0033] (see [4])

FIG. 3



[0059] (see [1.A])

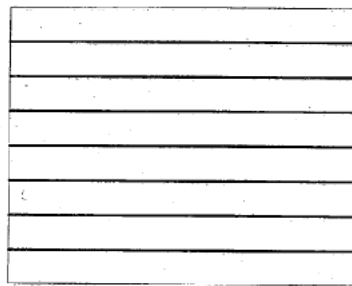


FIG. 4A

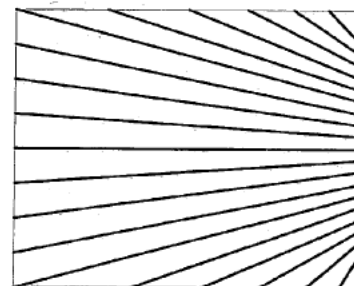


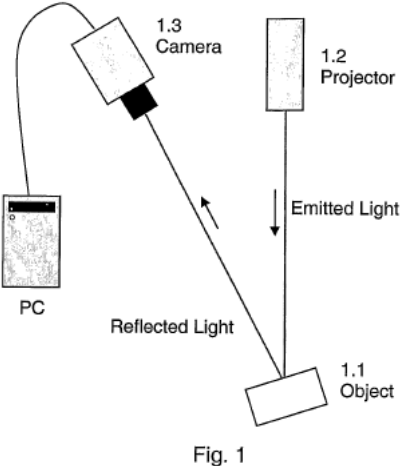
FIG. 4B

[0060] (see [1.F])

See also, [0062], [0074].

Vinther also discloses this claim element.

Vinther discloses that a line extending between the optical center of the projector and the optical center of the camera may not be perpendicular to the camera optical axis.

'656 Claim	Tomasi in view of Vinther
	 Fig. 1
7. The system of claim 1, wherein the light projector projects structured light in a wavelengths selected from optical, visible and infrared wavelengths.	Tomasi discloses this claim element. Tomasi discloses the use of visible and invisible structured light. [0034] (<i>see</i> [1.A]) [0036] (<i>see</i> [1A]) [0037] (“The pattern projected on the scene 102 may be visible, or it could be formed with invisible light when it is undesirable to reveal the array. For example, infrared light may be used when the infrared spectrum is easier to distinguish from ambient light. The projected light may be pulsed in synchrony with a shutter in the camera 120, so as to optimize the ratio of projected versus ambient light.”) <i>See also</i>, [0004], [0006], [0024], [0025], [0026], [0027], [0028], [0038]. Vinther also discloses this claim element. Vinther discloses the use of visible or invisible structured light.

'656 Claim	Tomasi in view of Vinther
	6:31-7:2 (<i>see</i> [1.A]) <i>See also, 1:14-17, 2:1-2, 2:31-32, 8:28-30.</i>
8. The system of claim 1, wherein the light projector is a flashlight source.	Tomasi discloses this claim element. Tomasi discloses a projector that projects light using a bulb. [0034] (<i>see</i> [1.A]) [0037] (<i>see</i> [7]) <i>See also, [0004], [0006], [0024], [0025], [0026], [0027], [0028], [0038].</i> Vinther also discloses this claim element. Vinther discloses a light source in a conventional projector. A POSITA would know that such conventional light source could be a bulb (flashlight source). 6:31-7:2 (<i>see</i> [1.A]) <i>See also, 1:14-17, 2:1-2, 2:31-32, 8:28-30.</i>
9. The system of claim 1, wherein the structured light pattern comprises a plurality of coded elements that can be variably grouped together such that all of the coded elements in each group form a unique sequence relative to the sequences of	Tomasi discloses this claim element. Tomasi discloses groups of unique sequences of coded elements located along varying virtual lines.

'656 Claim

coded elements in adjacent groups of coded elements.

Tomasi in view of Vinther

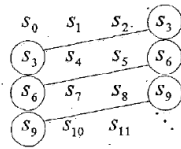


FIG. 7

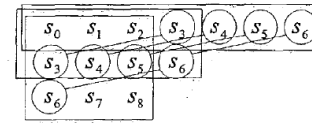


FIG. 8

$s_0 \quad s_1 \quad s_2 \quad b_0 \quad s_3 \quad s_4 \quad s_5 \quad b_6 \dots$
 $s_3 \quad s_4 \quad s_5 \quad b_1 \quad s_6 \quad s_7 \quad s_8 \quad b_7 \dots$
 $s_6 \quad s_7 \quad s_8 \quad b_2 \quad s_9 \quad s_{10} \quad s_{11} \quad b_8 \dots$
 $b_3 \quad b_4 \quad b_5 \quad d \quad b_9 \quad b_{10} \quad b_{11} \quad d \dots$

FIG. 9

[0060] (see [1.F])

[0092] (see [1.E])

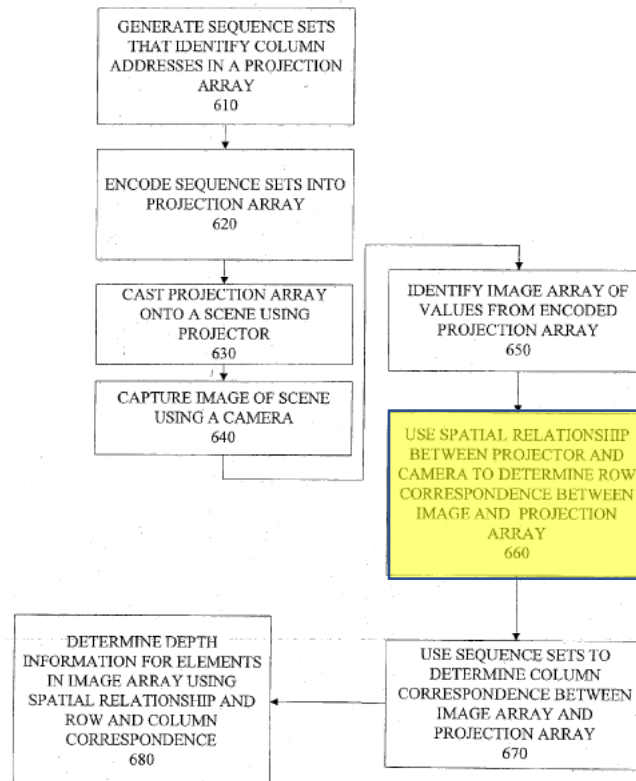
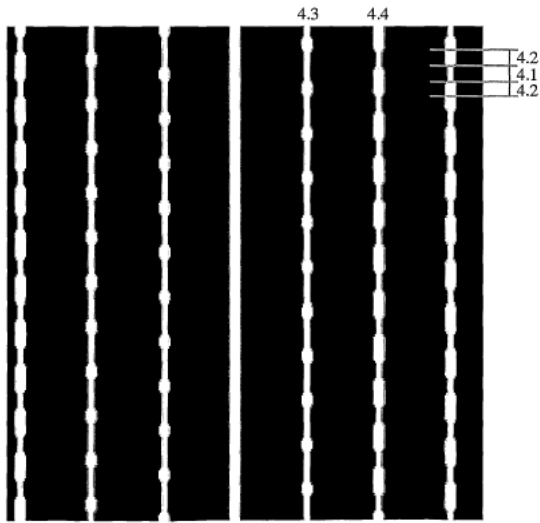
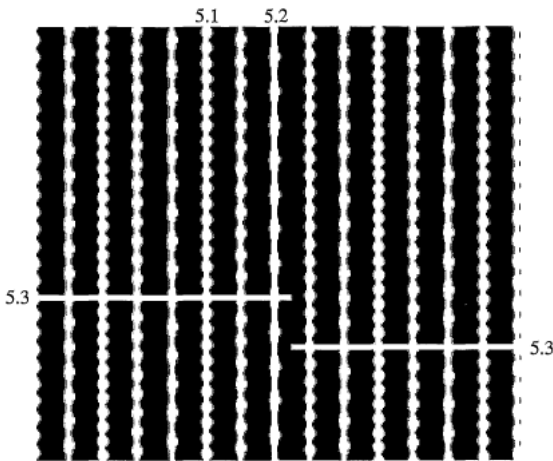
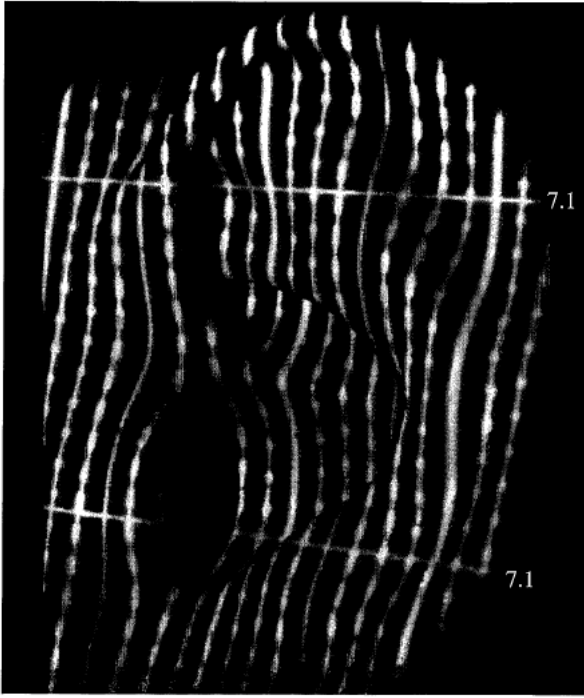


FIG. 6

'656 Claim	Tomasi in view of Vinther
	<i>See also, [0059], [0074], [0075], [0090].</i> Vinther also discloses this claim element. Vinther discloses groups of unique sequences of coded elements located along varying virtual lines.  Fig. 4  Fig. 5

'656 Claim	Tomasi in view of Vinther
	 Fig. 7 7:18-35 (<i>see</i> [1.E]) 8:21-25 (<i>see</i> [1.E])
10. The system of claim 1, wherein the computing device determines a three-dimensional shape of the surface of said object.	Tomasi discloses this claim element. Tomasi discloses the use of structured light to determine the shape of a three-dimensional surface. [0003] (<i>see</i> [1.PREAMBLE])

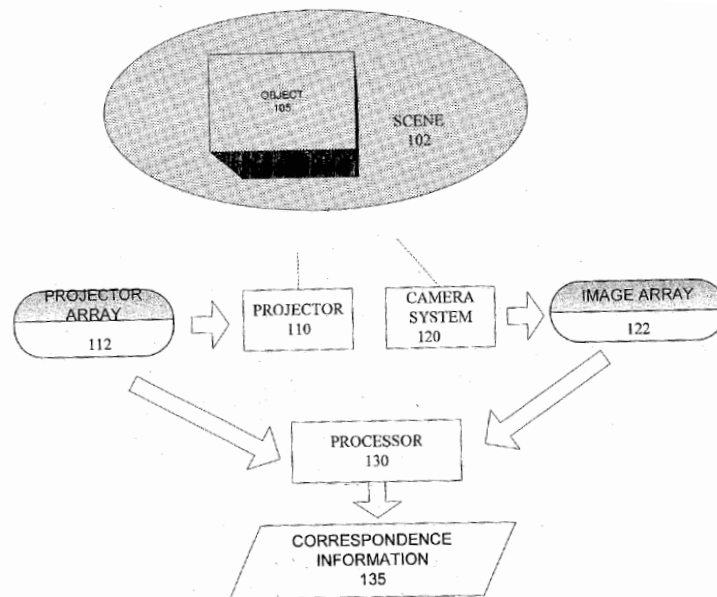


FIG. 1

[0032] (“FIG. 1 describes an image correspondence system, under an embodiment of the invention. As will be described, an image correspondence system may be used to optically observe an object and **determine three dimensional features, characteristics and other information of the object.**”)

See also, [0004], [0022], [0125].

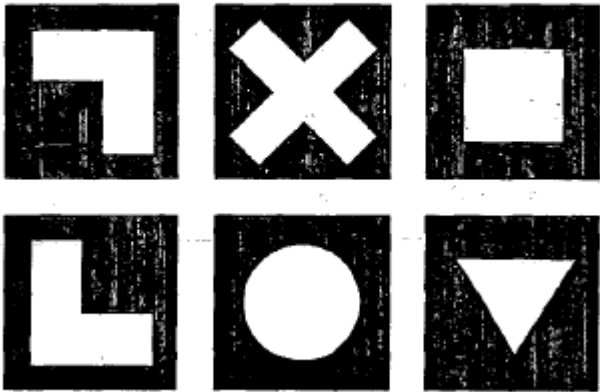
Vinther also discloses this claim element.

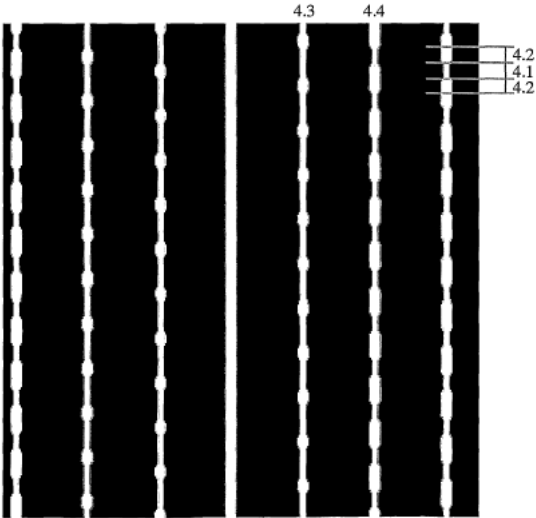
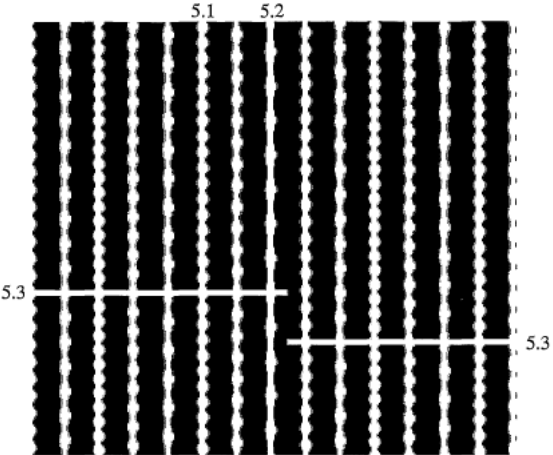
Vinther discloses the use of structured light to determine the shape of a three-dimensional surface.

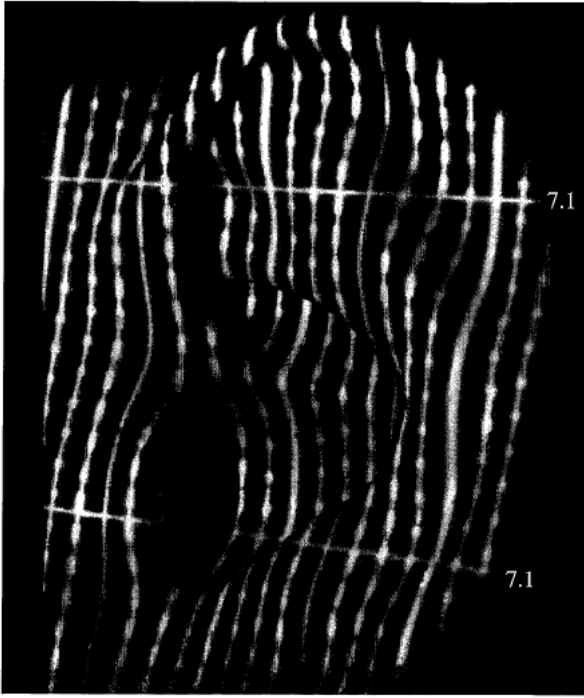
Abstract (*see* [1.PREAMBLE])

1:14-17 (*see* [1.C])

8:30-32 (*see* [1.C])

'656 Claim	Tomasi in view of Vinther
	9:2-7 (<i>see</i> [1.C])
11. The system of claim 1, wherein said at least one parameter defines a shape, size, or color or a change thereof in time for at least one of said coded elements.	Tomasi discloses that at least one parameter defines a shape, size, or color or a change thereof in time for at least one of said coded elements. Tomasi discloses a size and shape of the coded elements. FIG. 10  [0035] (<i>see</i> [1.D]) [0089] (<i>see</i> [1.D]) [0090] (<i>see</i> [1.D]) [0091] (<i>see</i> [1.D]) <i>See also</i>, [0006], [0021], [0024], [0038], [0075], [0076], [0103], claims 1, 12, 16, 35. Vinther also discloses this claim element. Vinther discloses a plurality of coded elements of a predetermined size that are spatially distributed and have varying amplitude.

'656 Claim	Tomasi in view of Vinther
	 Fig. 4  Fig. 5

'656 Claim	Tomasi in view of Vinther
	 Fig. 7 7:18-35 (<i>see</i> [1.E]) 8:21-25 (<i>see</i> [1.E])
12. A method for the 3D measurement of the shape of a material object, comprising:	Tomasi in view of Vinther discloses this claim element. <i>See</i> claim [1.Preamble].
projecting a structured light pattern from a light projector onto a surface of an object, wherein the light projector comprises a light source, a slide with a slide pattern located on a	Tomasi in view of Vinther discloses this claim element. <i>See</i> claim [1.A].

'656 Claim	Tomasi in view of Vinther
slide surface, and a projector lens characterized by a projector lens vertex;	
capturing an image of the structured light pattern reflected on the surface of the object with a device for capturing an image, wherein said device for capturing an image comprises a device lens characterized by a device lens vertex;	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.B].</i>
determining a measurement relating to the surface of the object using a triangulation algorithm based on a correspondence between points in said slide pattern and said image, and	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.C].</i>
wherein said slide pattern comprises a plurality of coded elements, where each of said coded elements is characterized by at least one parameter and, where said at least one parameter	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.D].</i>

'656 Claim	Tomasi in view of Vinther
defines a spatial or temporal distribution of an amplitude or a wavelength of said structured light, and	
wherein said coded elements are assigned to one of at least first group or second group, each of which first group and second group comprising at least two of said coded elements, and	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.E].</i>
wherein at least a first slide virtual line and a second slide virtual line are defined on said slide surface, where said first slide virtual line is defined by an intersection between said slide surface and a first plane passing through said projector lens vertex and through said device lens vertex, and said second slide virtual line is defined by an intersection between said slide surface and a	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.F].</i>

'656 Claim	Tomasi in view of Vinther
second plane passing through said projector lens vertex and through said device lens vertex, and	
wherein said coded elements of said first group are located along said first virtual line and said coded elements of said second group are located along said second virtual line.	Tomasi in view of Vinther discloses this claim element. <i>See claim [1.G].</i>
13. The method of claim 12, wherein each of said coded elements having at least three points that do not lie on a straight line.	Tomasi in view of Vinther discloses this claim element. <i>See claim 2.</i>
14. The method of claim 12, wherein at least first object virtual line and second object virtual line are defined on said surface of said object, where said first object virtual line is defined by an intersection between said surface of said	Tomasi in view of Vinther discloses this claim element. <i>See claim 3.</i>

'656 Claim	Tomasi in view of Vinther
object and said first plane and where said second object virtual line is defined by an intersection between said surface of said object and said second plane.	
15. The method of claim 12, wherein the light projector is further characterized by a central optical axis, further comprising arranging the light projector and the device for capturing an image such that a line extending between the light projector vertex and the device vertex is perpendicular to the central optical axis of the light projector.	Tomasi in view of Vinther discloses this claim element. <i>See</i> claim 4.
17. The method of claim 12, wherein the light projector is characterized by a projector central optical axis and wherein the device for capturing an	Tomasi in view of Vinther discloses this claim element. <i>See</i> claim 6.

'656 Claim	Tomasi in view of Vinther
image is characterized by a device central optical axis, further comprising arranging the light projector and the device for capturing an image such that a line extending between the projector vertex and the device vertex is not perpendicular to either the projector central optical axis or the device central optical axis.	
18. The method of claim 12, further comprising projecting structured light in a wavelengths selected from optical, visible and infrared wavelengths.	Tomasi in view of Vinther discloses this claim element. <i>See claim 7.</i>
19. The method of claim 12, further comprising projecting the structured light from a flashlight source.	Tomasi in view of Vinther discloses this claim element. <i>See claim 8.</i>

'656 Claim	Tomasi in view of Vinther
20. The method of claim 12, wherein the structured light pattern comprises a plurality of coded elements that can be variably grouped together such that all of the coded elements in each group form a unique sequence relative to the sequences of coded elements in adjacent groups of coded elements.	Tomasi in view of Vinther discloses this claim element. <i>See claim 9.</i>
21. The method of claim 12, further comprising determining a three-dimensional shape of the surface of said object.	Tomasi in view of Vinther discloses this claim element. <i>See claim 10.</i>
22. The method of claim 1, wherein said at least one parameter defines a shape, size, or color or a change thereof in time for at least one of said coded elements.	Tomasi in view of Vinther discloses this claim element. <i>See claim 11.</i>

B. Ground 2: Tomasi in View of Vinther and further in view of Vuylsteke

1. Overview of Vuylsteke and Motivation to Modify Tomasi (in view of Vinther) with Vuylsteke

Vuylsteke discloses a system and method for the 3D measurement of the shape of a three-dimensional scene. EX1006, 148. **Vuylsteke** further seeks to solve the correspondence problem between points in a captured image and in the slide pattern. *Id.*, 148-149.

Vuylsteke discloses a system using a projector, a camera, and a computer for 3D imaging.

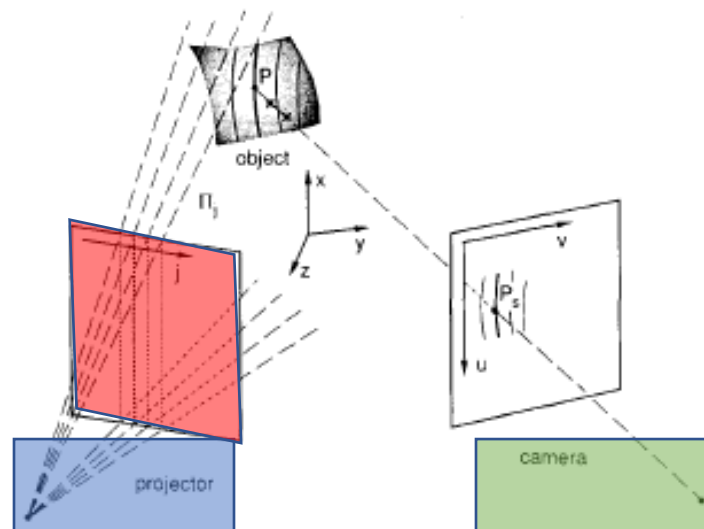


Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j . The index value j is required to compute the coordinates of the actual object point P .



Fig. 2. Detail of the projected binary pattern.

Id., 149. For example, **Vuylsteke** discloses that “[t]he **illumination pattern depicted in Fig. 2** has been recorded on a **24 X 36 mm Ortho-negative** and is projected on the scene with **a standard slide projector** equipped with a 250 W xenon bulb and a 90 mm/f 1:2.5 objective.” *Id.*, 153. In addition, **Vuylsteke** discloses that a camera is used to capture an image. “The **camera** (High Technology Holland, MX type) has a MOS-CCD frame transfer image sensor of 604(H) x 576(V) pixels. . . . The focal length of the camera objective (16 mm/f 1:1.8) has been matched to the projection optics, such that approximately the entire illumination pattern is visible when it is projected on a frontal surface at nominal depth.” *Id.*, 153.

Vuylsteke further describes that a computer is used to execute a triangulation algorithm that uses corresponding points in the slide pattern and the captured image for measuring 3D object geometry. “The digitized picture is processed by **a VAX-750 minicomputer**. Demodulating and decoding an illumination-encoded image comprise the following steps: 1) detecting the grid points, estimating their precise location in the image, determining their appearance

(‘sign’) in the chess-board, and their individual codebit indicated by a bright or dark spot; 2) searching for the closest N-, S-, W-, and eastern neighbors of every detected grid point, i.e., recovering the local grid context in the image; and 3) identifying grid points by their local signature, using dynamic windows of some specified minimal size, and checking for signature consistency. Identified points are next spatially located by triangulation.” *Id.*, 153.

Vuylsteke also discloses that coded elements can be grouped along virtual lines.

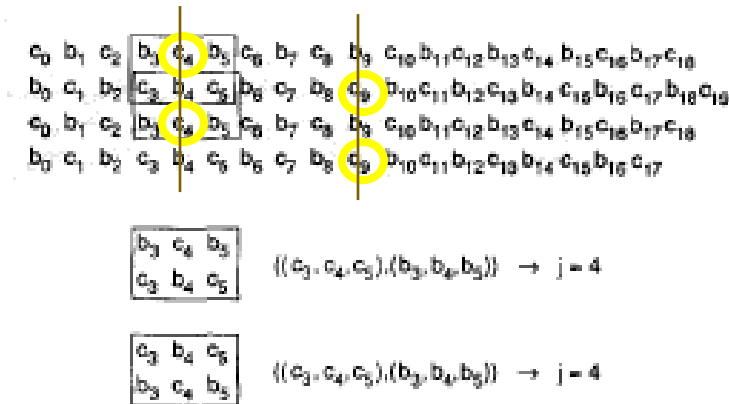


Fig. 4. Two binary sequences are bit-wise assigned to the grid such that every window of 2×3 bits has a unique signature in every position when it is shifted horizontally. Points of the “+” type are marked with a bit of the $\{c_i\}$ sequence, and those of the “-” type with a bit of $\{b_i\}$. The assignment is repeated every second row.

Id., 150. “In general, if the identification should be based on a $t \times b$ window format, then the bit map must be organized such that any t consecutive rows provide for independent information. This requirement may be achieved by repeating the bit assignment every t rows. In the simplest case when the bit map is

composed of equal rows ($t = 1$) the appropriate identification window format would be very elongated (covering at least 6 adjacent grid points in horizontal direction, if 63 column positions have to be identified).” *Id.*, 151. In addition, Vuylsteke discloses that epipolar geometry can be used to resolve correspondence ambiguity. “If a point grid (or an orthogonal line grid) is projected instead of a parallel line grid, then the ambiguity may be alleviated by taking into account the discrete nature of the projected grid [14], [15], or it may even be eliminated by applying the epipolar constraint several times in a dynamic configuration where the projector is successively rotated [16].” *Id.*, 148.

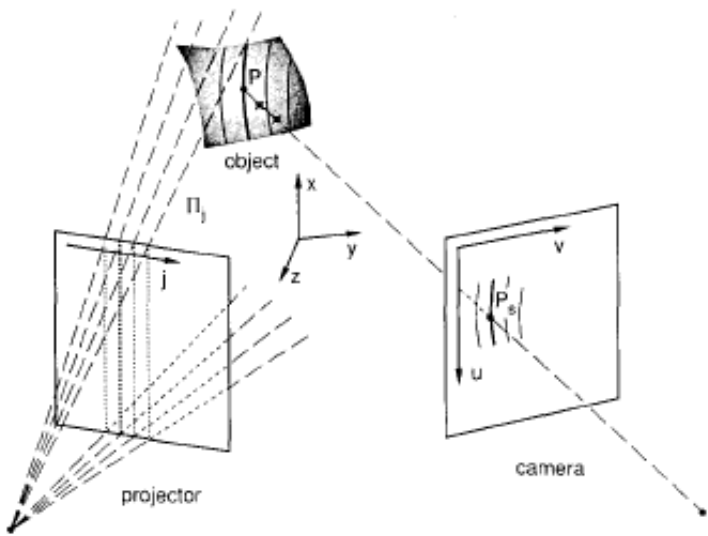
Tomasi, **Vinther**, and **Vuylsteke** are analogous prior art and in the same field as the ‘656—three-dimensional modeling of an object surface—and pertinent to the alleged problems identified in the ‘656 of correspondence between points in the captured image and the slide pattern. *See, e.g.*, EX1001, 4:40-5:19, 5:55-6:2.

In light of the above teachings, a POSITA would have had a motivation and a reasonable expectation of success in modifying **Tomasi** with **Vinther’s** teachings by using, for example, **Vuylsteke’s** grouping of coded light symbols within the structured light pattern. As previously discussed in section IX.A, **Tomasi** and **Vinther** teach using structured light patterns having varying coded bits that can be grouped. EX1004, [0035], EX1005, 7:18-19. **Vuylsteke** also discloses coded elements that can be grouped. EX1006, 150. Indeed, it was also well understood

for a designer of a system at the time of the invention to look to other 3D scanning implementations for guidance. *See, e.g.*, section IX.A.2. Modifying **Tomasi** in view of **Vinther** with **Vuylsteke**'s teachings would have been a straightforward application of those teachings in a manner that advantageously improves the efficiency of a 3D scanning system. EX1003, ¶¶57-63.

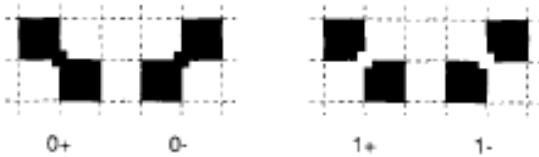
2. Claim Chart

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
1. [1.PREAMBLE] A system for the 3D measurement of the shape of a material object, comprising:	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.PREAMBLE]. Vuylsteke discloses this claim element. Vuylsteke discloses using structured light to acquire range pictures of three-dimensional scenes. p. 148 (“Triangulation with structured light is a well established technique for acquiring range pictures of three-dimensional scenes. The spatial position of a point is uniquely determined as the intersection of a straight line with a plane, of three planes, or as the intersection of two straight lines within a plane. These geometric principles have been applied in wide range of simple triangulation techniques, using a directional illumination device (a projector), and a directional sensor (a TV-camera). The basic schemes use a directed light beam to indicate a single object point [1]-[3], or a light sheet to indicate a cross-section of the visible scene surface [4]-[6].”)
[1.A] a light projector for projecting a structured light pattern onto a surface	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.A]. Vuylsteke discloses this claim element.

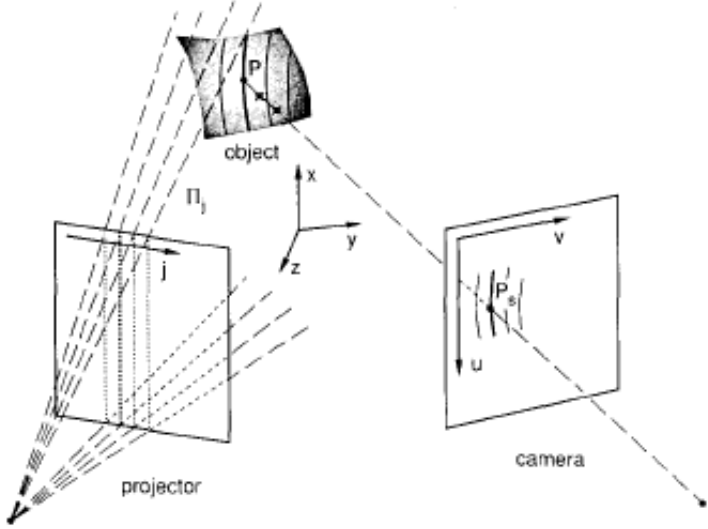
'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
of said object, wherein said light projector comprises a light source, a slide with a slide pattern located on a slide surface, and a projector lens characterized by a projector lens vertex;	Vuylsteke discloses a projector that projects a structured light pattern onto the surface of an object.  Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149 Vuylsteke explains that the projector includes a light source. p. 149 (“It is therefore essential to restrict the encoding process to a single instance (e.g., by means of a flash light source), such that all the information required for identifying the indicated scene points is available in a single camera picture.”) Vuylsteke discloses a projector having a slide with slide pattern on the slide and a lens, which has a lens vertex. p. 153 (“We realized a prototype based on this binary encoding principle. The measurement setup is very simple and it involves no moving parts. The basic geometry is sketched in Fig. 1. The illumination pattern depicted in Fig. 2 has been recorded on a 24

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	X 36 mm Ortho-negative and is projected on the scene with a standard slide projector equipped with a 250 W xenon bulb and a 90 mm/f 1:2.5 objective. The entire pattern consists of 64 rows by 63 columns.”)
[1.B] a device for capturing an image of said structured light pattern reflected on said object, wherein said device for capturing an image comprises a device lens characterized by a device lens vertex; and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.B]. Vuylsteke discloses this claim element. Vuylsteke discloses a camera for capturing images. It further describes that the focal length is designed to match that of the projector optics. p. 153 (“The camera (High Technology Holland, MX type) has a MOS-CCD frame transfer image sensor of 604(H) x 576(V) pixels. It delivers a 625-line CCIR video signal (linear response, constant gain), which is sampled and digitized to a 512 X 512 by 8 bit digital picture with 1:1 aspect ratio. The focal length of the camera objective (16 mm/f 1:1.8) has been matched to the projection optics, such that approximately the entire illumination pattern is visible when it is projected on a frontal surface at nominal depth. In that case the observed grid period roughly corresponds to 8 pixels in both directions.”)
[1.C] a computing device for determining a measurement relating to the shape of said object using a triangulation algorithm based on a correspondence between points in said slide pattern and said image, and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.C]. Vuylsteke discloses this claim element. Vuylsteke discloses that triangulation with structured light is a well-established technique. p. 148 (<i>see</i> [1.PREAMBLE]) Vuylsteke describes the computer used to execute the triangulation algorithm.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	p. 153 (“The digitized picture is processed by a VAX-750 minicomputer. Demodulating and decoding an illumination-encoded image comprise the following steps: 1) detecting the grid points, estimating their precise location in the image, determining their appearance (‘sign’) in the chess-board, and their individual codebit indicated by a bright or dark spot; 2) searching for the closest N-, S-, W-, and eastern neighbors of every detected grid point, i.e., recovering the local grid context in the image; and 3) identifying grid points by their local signature, using dynamic windows of some specified minimal size, and checking for signature consistency. Identified points are next spatially located by triangulation.”)
[1.D] wherein said slide pattern comprises a plurality of coded elements, where each of said coded elements is characterized by at least one parameter and, where said at least one parameter defines a spatial or temporal distribution of an amplitude or a wavelength of said structured light, and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.D]. Vuylsteke discloses this claim element. Vuylsteke discloses that it was known to use a slide pattern with varying wavelength. p. 148 (“Tajima used a single monochromatic illumination pattern with gradually increasing wavelength (i.e., a rainbow pattern), in combination with a two-channel color camera [18].”) Vuylsteke discloses a slide pattern with a plurality of coded elements, spatially distributed and having varying amplitude. p. 150 (“An appropriate illumination pattern with only two intensity levels which 1) indicates a grid of points and 2) marks each grid point individually with a single codebit, is depicted in Fig. 2. Note the basic chess-board appearance. By definition, the grid points to be indicated on the scene are located at the intersection of the horizontal and vertical chess-board edges, i.e., where

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	four squares meet. Upon projection every column generates a plane Π, the index j of which must be known for locating the indicated object points by triangulation. In our experimental measurement system the entire pattern consists of 63 columns of 64 points each (only 10 rows are shown). For the purpose of identification every grid point is individually marked with a bright or a dark spot, representing a binary “1” or “0”, respectively. Additionally the chess-board naturally exhibits two basic appearances of the grid points, which alternate both in horizontal and vertical direction. We denote them as either “+” or “-”. Hence one may think of the complete pattern to be composed of the four primitives depicted in Fig. 3.”)  Fig. 2. Detail of the projected binary pattern.  Fig. 3. The entire illumination pattern is composed of four primitives.
[1.E] wherein said coded elements are assigned to one of at least first group or second group, each of which first group and second group comprising at least	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.E]. Vuylsteke discloses this claim element. Vuylsteke discloses groups of coded elements, containing at least two coded elements.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
two of said coded elements, and	p. 151 (“For any arbitrary identification window format one may always define an equivalent <i>n</i>-tuple with a specified order of c_k- and b_k-bits, <i>n</i> being the total number of bits in the window. The window even need not be rectangular. For some specified window format the corresponding <i>n</i>-tuple may be regarded as a codeword, and the set of all the codewords which are obtained by considering the window at every horizontal position on the bit map defines a code. Every window format defines a distinct code. If the identification is to be performed with a window of some specified format, say $2 \times b$ bits, then a pair of binary sequences $\{c_k\}$ and $\{b_k\}$ should be found such that the corresponding code is optimal, in the sense that it has the largest possible minimal Hamming distance.”)
[1.F] wherein at least a first slide virtual line and a second slide virtual line are defined on said slide surface, where said first slide virtual line is defined by an intersection between said slide surface and a first plane passing through said projector lens vertex and through said device lens vertex, and said second slide virtual line is defined by an intersection between said slide surface and a second plane passing through said projector lens vertex and through said	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.F]. Vuylsteke discloses this claim element. Vuylsteke discloses light sheets (planes) projected through the projector lens vertex, and virtual planes passing through the projector lens vertex and the camera lens vertex. The structured light pattern is designed in a grid-like fashion such that defined rows and columns intersect with the light sheets.

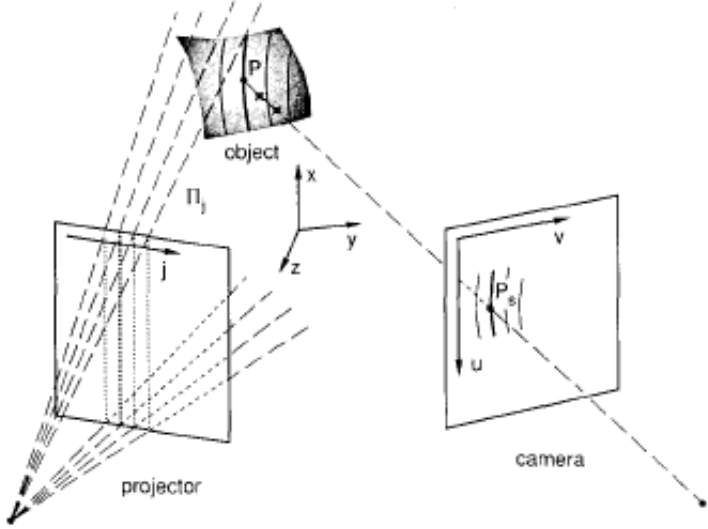
'656 Claim	Tomasini in view of Vinther further in view of Vuylsteke
device lens vertex, and	 Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149 Vuylsteke describes how it performs decoding by using grid points along certain virtual rows and/or columns. p. 148 (<i>see</i> [1.PREAMBLE]) p. 155 (“We estimated the precision of this subpixel location technique by means of the following experiment. If the illumination pattern is projected on a flat target then ideally every set of grid points belonging to the same row or column should be collinear in the camera image. In our test procedure collinearity is examined by fitting lines to the rows and columns of located grid points in the image, according to the least squared error criterion.”) “The previous steps served to characterize every detected grid point by its image coordinates, its “sign,” and its corresponding codebit. For the purpose of identification, however, windows of adjacent grid points are to be considered instead of isolated grid points. The

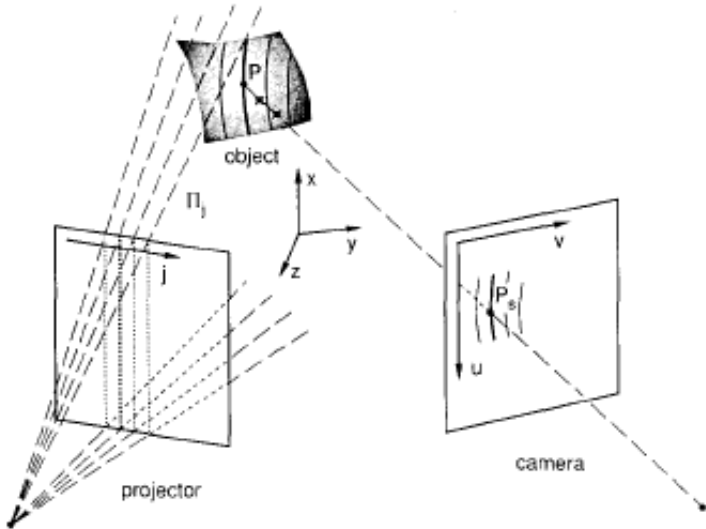
'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	actual configuration of codebits in a window determines a signature by which the enclosed grid points can be identified. Hence the first decoding step consists of locally recovering the original grid topology in the observed image, i.e., finding the natural N-, S-, W-, and E-neighbors of any detected grid point. A directed graph, with a node for every detected grid point, and branches to the immediate 4-neighbors, is very convenient to represent these relational data.” “Finding neighboring grid points may be facilitated by invoking some heuristics, which follow from geometrical considerations. The geometry of our experimental system (depicted in Fig. 1) is subject to some weak restrictions, which we denote by a “usual” triangulation setup: 1) the projector and the camera point to some common point so as to optimally cover the working space; 2) their mutual separation (base length) is small compared to the nominal object distance; 3) the focal length/image size ratios of the projector and the camera are nearly equal and relatively large; and 4) the <i>j</i>-axis does not deviate very much from the base line direction (i.e., the line through both lens centers). Under these circumstances the grid rows will be observed as nearly parallel and equidistant in the camera image. In other words, the direction and vertical separation of the grid rows is only to a small extent modulated by the scene geometry.”)
[1.G] wherein said coded elements of said first group are located along said first virtual line and said coded elements of said second group are located along said second virtual line.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, [1.G]. Vuylsteke discloses this claim element. Vuylsteke discloses groups of coded elements located along varying virtual lines.

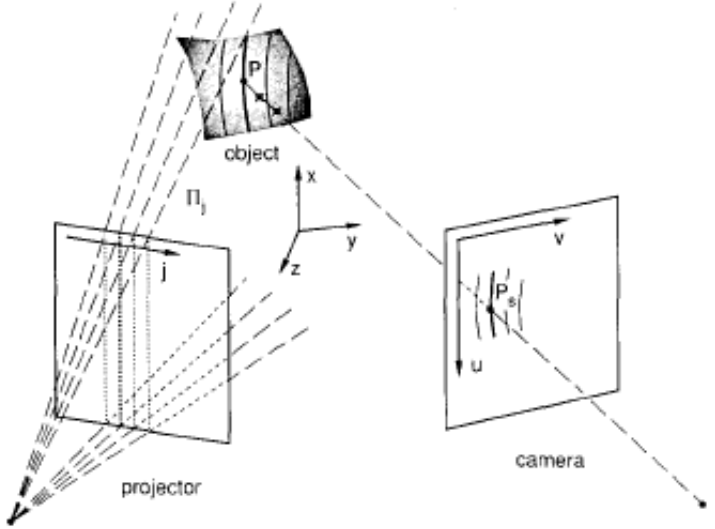
'656 Claim	Tomas in view of Vinther further in view of Vuylsteke
	Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149 Vuylsteke discloses how triangulation with structured light involves the intersection of lines and planes. p. 148 (<i>see</i> [1.PREAMBLE]) Vuylsteke shows how codebits exist within the context of columns and planes. p. 150 (<i>see</i> [1.D])

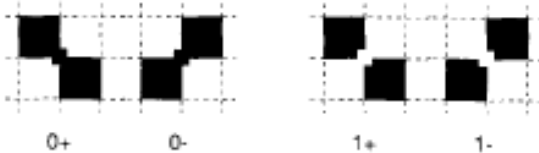
'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	 Fig. 2. Detail of the projected binary pattern.  Fig. 3. The entire illumination pattern is composed of four primitives. Vuylsteke discloses groups of coded elements, containing at least two coded elements. p. 151 (<i>see</i> [1.E]) Vuylsteke describes how coded elements exist in the context of a grid topology. p. 155 (<i>see</i> [1.F])
2. The system of claim 1, wherein each of said coded elements having at least three points that do not lie on a straight line.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 2. Vuylsteke discloses this claim element. Vuylsteke shows that codes elements consist of squares of light at intersections of a checkerboard layout. The vertices of a square do not lie on a straight line. p. 150 (<i>see</i> [1.D])

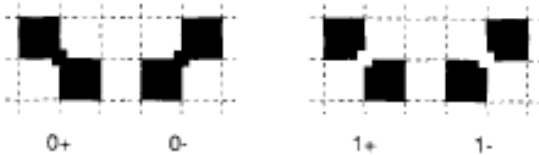
'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	 Fig. 2. Detail of the projected binary pattern.  Fig. 3. The entire illumination pattern is composed of four primitives.
3. The system of claim 1, wherein at least first object virtual line and second object virtual line are defined on the surface of said object, where said first object virtual line is defined by an intersection between said surface of said object and said first plane and where said second object virtual line is defined by an intersection between said surface of said object and said second plane.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 3. Vuylsteke discloses this claim element. Vuylsteke discloses light sheets (planes) projected through the projector lens vertex, and virtual planes passing through the projector lens vertex and the camera lens vertex. The structured light pattern is designed in a grid-like fashion such that defined rows and columns intersect with the light sheets.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
	 Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149 Vuylsteke discloses how triangulation with structured light involves the intersection of lines and planes with an object. p. 148 (see [1.PREAMBLE])
4. The system of claim 1, wherein the light projector is further characterized by a central optical axis, further wherein the light projector and the device for capturing an image are arranged such that a line extending between the projector vertex and the device vertex is	Tomasi in view of Vinther discloses this element. See section IX.A.3, claim 4. To the extent this claim element is not explicitly disclosed in Vuylsteke, one of ordinary skill in the art would have considered it an obvious addition to or modification of the disclosure. A person of ordinary skill in the art would have been motivated to combine the disclosure with other disclosures, such as those in Tomasi and Vinther, to arrive at this claim.

'656 Claim	Tomasí in view of Vinther further in view of Vuylsteke
perpendicular to the central optical axis of the light projector.	
6. The system of claim 1, wherein the light projector is characterized by a projector central optical axis and wherein the device for capturing an image is characterized by a device central optical axis, further wherein the light projector and the device for capturing an image are arranged such that a line extending between the projector vertex and the device vertex is not perpendicular to either the projector optical axis or the device optical axis.	Tomasí in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 6. Vuylsteke discloses this claim element. Vuylsteke discloses projector and camera orientations such that the projector and camera optical axes are acute angles with respect to the line between the optical centers.  Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_s on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149
7. The system of claim 1, wherein the light projector projects structured light in a wavelengths selected from optical,	Tomasí in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 7. Vuylsteke discloses this claim element. Vuylsteke discloses the use of visible structured light.

‘656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
visible and infrared wavelengths.	p. 148 (<i>see</i> [1.PREAMBLE])
8. The system of claim 1, wherein the light projector is a flashlight source.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 8. Vuylsteke discloses this claim element. Vuylsteke shows a projector that projects a structured light pattern onto the surface of an object.  Fig. 1. The identification problem with multiple stripe triangulation. An observed image point P_j on a light stripe may correspond to any of the projected light sheets Π_j. The index value j is required to compute the coordinates of the actual object point P. p. 149 Vuylsteke explains that the projector includes a flashlight source. p. 149 (<i>see</i> [1.A])
9. The system of claim 1, wherein the structured light pattern comprises a plurality of coded	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 9. Vuylsteke discloses this claim element.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
elements that can be variably grouped together such that all of the coded elements in each group form a unique sequence relative to the sequences of coded elements in adjacent groups of coded elements.	Vuylsteke discloses groupings of coded elements that are unique from other groups. p. 150 (<i>see</i> [1.D])  Fig. 2. Detail of the projected binary pattern.  Fig. 3. The entire illumination pattern is composed of four primitives. p. 151 (<i>see</i> [1.E])
10. The system of claim 1, wherein the computing device determines a three-dimensional shape of the surface of said object.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 10. Vuylsteke discloses this claim element. Vuylsteke discloses the use of structured light to determine the shape of a three-dimensional surface. p. 148 (<i>see</i> [1.PREAMBLE])
11. The system of claim 1, wherein said at least one parameter defines a shape, size, or color or a change thereof in time for at	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 11. Vuylsteke discloses this claim element.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
least one of said coded elements.	Vuylsteke discloses a plurality of coded elements of a predetermined size that are spatially distributed and having varying amplitude. p. 150 (<i>see</i> [1.D])  Fig. 2. Detail of the projected binary pattern.  Fig. 3. The entire illumination pattern is composed of four primitives.
12. A method for the 3D measurement of the shape of a material object, comprising:	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke also discloses this claim element. <i>See</i> claim [1.PREAMBLE].
projecting a structured light pattern from a light projector onto a surface of an object, wherein the light projector comprises a light source, a slide with a slide pattern located on a slide surface, and a projector lens	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.A].

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
characterized by a projector lens vertex;	
capturing an image of the structured light pattern reflected on the surface of the object with a device for capturing an image, wherein said device for capturing an image comprises a device lens characterized by a device lens vertex;	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.B].
determining a measurement relating to the surface of the object using a triangulation algorithm based on a correspondence between points in said slide pattern and said image, and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.C].
wherein said slide pattern comprises a plurality of coded elements, where each of said coded elements is characterized by at least one parameter and, where said at least one parameter defines a spatial or temporal distribution of an amplitude or a	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.D].

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
wavelength of said structured light, and	
wherein said coded elements are assigned to one of at least first group or second group, each of which first group and second group comprising at least two of said coded elements, and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.E].
wherein at least a first slide virtual line and a second slide virtual line are defined on said slide surface, where said first slide virtual line is defined by an intersection between said slide surface and a first plane passing through said projector lens vertex and through said device lens vertex, and said second slide virtual line is defined by an intersection between said slide surface and a second plane passing through said projector lens vertex and through said device lens vertex, and	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12. Vuylsteke discloses this claim element. <i>See</i> claim [1.F].
wherein said coded elements of said first	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 12.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
group are located along said first virtual line and said coded elements of said second group are located along said second virtual line.	Vuylsteke discloses this claim element. <i>See</i> claim [1.G].
13. The method of claim 12, wherein each of said coded elements having at least three points that do not lie on a straight line.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 13. Vuylsteke discloses this claim element. <i>See</i> claim 2.
14. The method of claim 12, wherein at least first object virtual line and second object virtual line are defined on said surface of said object, where said first object virtual line is defined by an intersection between said surface of said object and said first plane and where said second object virtual line is defined by an intersection between said surface of said object and said second plane.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 14. Vuylsteke discloses this claim element. <i>See</i> claim 3.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
15. The method of claim 12, wherein the light projector is further characterized by a central optical axis, further comprising arranging the light projector and the device for capturing an image such that a line extending between the light projector vertex and the device vertex is perpendicular to the central optical axis of the light projector.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 15. <i>See</i> claim 4.
17. The method of claim 12, wherein the light projector is characterized by a projector central optical axis and wherein the device for capturing an image is characterized by a device central optical axis, further comprising arranging the light projector and the device for capturing an image such that a line extending between the projector vertex and the device vertex is not perpendicular to	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 17. Vuylsteke discloses this claim element. <i>See</i> claim 6.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
either the projector central optical axis or the device central optical axis.	
18. The method of claim 12, further comprising projecting structured light in a wavelengths selected from optical, visible and infrared wavelengths.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 18. Vuylsteke discloses this claim element. <i>See</i> claim 7.
19. The method of claim 12, further comprising projecting the structured light from a flashlight source.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 19. Vuylsteke discloses this claim element. <i>See</i> claim 8.
20. The method of claim 12, wherein the structured light pattern comprises a plurality of coded elements that can be variably grouped together such that all of the coded elements in each group form a unique sequence relative to the sequences of coded elements in adjacent groups of coded elements.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 20. Vuylsteke discloses this claim element. <i>See</i> claim 9.

'656 Claim	Tomasi in view of Vinther further in view of Vuylsteke
21. The method of claim 12, further comprising determining a three-dimensional shape of the surface of said object.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 21. Vuylsteke discloses this claim element. <i>See</i> claim 10.
22. The method of claim 1, wherein said at least one parameter defines a shape, size, or color or a change thereof in time for at least one of said coded elements.	Tomasi in view of Vinther discloses this element. <i>See</i> section IX.A.3, claim 22. Vuylsteke discloses this claim element. <i>See</i> claim 11.

X. SECONDARY CONSIDERATIONS

There is no evidence in the '656's prosecution history or elsewhere supporting any secondary considerations arguments, or evidence of nexus to any challenged Claim. *See generally* EX1002; EX1003, ¶64. Indeed, as demonstrated by the prior art referenced herein, any purported solutions to problems or unexpected results in the '656 were already well known. EX1003, ¶¶44-63. To the extent the PO asserts the existence of any secondary considerations in its responses, Petitioner reserves the right to address any such evidence.

XI. CONCLUSION

Substantial, new, and noncumulative technical teachings have been presented for '656 claims 1-4, 6-15, and 17-22, which are obvious for the reasons set forth above. EX1003, ¶44-63. There is reasonable likelihood that Petitioner will prevail as to the Claims. *Inter partes* review of claims 1-4, 6-15, and 17-22 is accordingly requested.

Dated: June 29, 2023

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE WITH WORD COUNT

Pursuant to 37 C.F.R. § 42.24(d), I certify that this paper complies with the type-volume limits of 37 C.F.R. § 42.24(b) because it contains 13,815 words, excluding the parts of this paper that are exempted by 37 C.F.R. § 42.24(a), according to the word processing system used to prepare this paper.

Dated: June 29, 2023

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CERTIFICATE OF SERVICE

The undersigned hereby certifies that a copy of the foregoing document and any accompanying exhibits were served at the following correspondence address of record for the subject patent via overnight delivery on June 29, 2023:

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