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(54) **DUAL-PATTERN OPTICAL 3D DIMENSIONING**

OPTISCHE 3D-DIMENSIONIERUNG MIT ZWEI MUSTERN

DIMENSIONNEMENT 3D OPTIQUE À DOUBLE MOTIF

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US-A- 4 914 460 **US-A1- 2016 328 854**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to optical dimensioning, and more particularly to dual-pattern optical 3D dimensioning.

BACKGROUND

[0002] Generally speaking, optical 3D dimensioning with structural light triangulation imaging (parallax) suffers accuracy loss introduced by variations in relative positions and orientations of a projector, camera, and projector-camera pair. These variations can result from thermal, structural, or other changes, such as component aging. The dimensioning accuracy problem can be partially solved with calibration, but the ultimate accuracy is still limited due to the non-calibratable part of variations, such as shock and vibration. In addition, temperature change of the system due to the ambient temperature change or self-generated heat may affect the triangular geometry. Temperature gradient change occurring due to the nonuniform heat-generating source and heat dissipation may introduce complex deformations to the triangular system geometry and individual components, and is hard to resolve by calibration. More specifically, changes in camera focusing and distortion may directly contribute to the 3D dimensioning error. Additionally, such changes are difficult to control or correct with calibration. Components of a camera module are usually made from multiple materials with significantly different thermal expansion coefficients (CTEs). For example, the materials may include silicon sensor with 3.5ppm/C, glass lens ~9ppm/C, aluminum barrel and holder 22ppm/C, plastic parts >60ppm/C. Such a combination makes it virtually impossible to fully compensate for the changes in pattern image positions on the image sensor introduced by the thermal expansion.

[0003] To overcome this issue, instead of the standard projector-camera pair triangulation, a dual-pattern optical 3D dimensioning system utilizing two or more identical projecting patterns may be applied to generate 3D depth data from dual-pattern image captured by the camera.

[0004] Several attempts have been made to address this issue. For example, in PCT Pat. App. No. WO 2014/011182 A1 by Gharib, convergence/divergence based depth determination techniques and uses with defocusing imaging are described. The system includes two projectors emitting converging red and blue light patterns, respectively (or alternatively, a single split beam), and a camera to capture the patterns. In Chinese Pat. App. No. CN 104050656 A (see also US 2015/0267701 A1), an apparatus and techniques for determining object depth in images are described. The system includes an emitter to project a low-resolution optical pattern and a high-resolution optical pattern, and a sensor to detect a composite image, which is then processed to obtain the depth information of the object in a range of different depths. However, none of these references mention projecting parallel light patterns, and determining the distance between neighboring points of the dual pattern for calculating the depth of the object. A paper "Development of Real Time 3-D Measurement System Using Intensity Ratio Method" by Miyasaka et al. describes a system for calculating depth of an object using intensity ratio method. The system includes a light source and video camera, wherein two types of light patterns, flat pattern and linear pattern, are projected alternatively onto the target object. Although the reference mentions calculating ratio of intensities of two different light patterns at a given pixel, it does not mention calculating ratio of distance between neighboring points, to determine the depth of the object. Furthermore, the reference does not mention using two light sources projecting dual parallel light patterns onto the target object. In US Pat. App. No. US 2016/0288330 A1 by Konolige, a system and method for depth sensing are described. The system includes a light source, a computing device, and two optical sensors separated by a fixed distance, each having a first set of multiple photodetectors to capture visible light, and a second set of multiple photodetectors to capture infrared light. The depth information obtained from both the visible and infrared light images is combined to determine a depth map of surfaces or objects. However, the reference does not mention using two projectors producing parallel light patterns simultaneously onto the target. Furthermore, the reference does not mention determining the distance between the neighboring light patterns and using it for calculating the depth of the target.

[0005] Therefore, a need exists for a system and method of accurate optical dimensioning.

US 20160328854 describes a distance sensor using diffractive optical elements to split a beam into multiple diverging projection beams.

US 4914460 describes using multiple beams of coherent light to determine distance and orientation of an object.

SUMMARY

[0006] The present invention in its various aspects is as set out in the appended claims.

[0007] In an exemplary embodiment, a dimensioning assembly includes, inter alia, a camera module; a first pattern generator, disposed near the camera module; a second pattern generator, disposed near the camera module and spaced apart from the first pattern generator, wherein the first and the second pattern projection assemblies are configured to generate identical patterns; and a processing system configured to detect and analyze positions of elements of the generated patterns.

[0008] In another exemplary embodiment, an optical dimensioning system includes, inter alia, one or more light emitting assemblies configured to project a predetermined pattern on an object; an imaging assembly configured to sense light scattered and/or reflected of the object, and to capture an image of the object while the pattern is projected; and a processing assembly configured to analyze the image of the object to determine dimension parameters of the object.

[0009] In another aspect, the present invention embraces a method for optical dimensioning. The method includes, inter alia, illuminating an object with at least two identical patterns; capturing an image of the illuminated object; and calculating dimensions of the object by analyzing pattern separation of the elements comprising the projected patterns.

[0010] The foregoing illustrative summary, as well as other exemplary objectives and/or advantages of the invention, and the manner in which the same are accomplished, are further explained within the following detailed description and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Figure 1A schematically depicts a dimensioning assembly, according to an embodiment.

Figure 1B schematically depicts a dual pattern produced by the dimensioning assembly, according to an embodiment.

Figures 2A-2D schematically depict relative positions of a camera module and pattern generators within a dimensioning assembly, according to embodiments.

Figure 3A schematically depicts an optical dimensioning system, according to an embodiment.

Figure 3B schematically depicts an optical dimensioning system with a relay lens, according to an embodiment.

Figure 4 schematically depicts a method for dual-pattern optical dimensioning, according to an embodiment.

DETAILED DESCRIPTION

[0012] The present invention in its various aspects is as set out in the appended claims.

[0013] Generally speaking, dual-pattern measurement allows extracting information based on a ratio of the image separation of the same point from two or more patterns to the image distance between adjacent points from the same pattern. Such an approach may offer various benefits compared to the traditional methods. For example, the camera can be at any location or orientation, and any variation in the relative position of the camera will not affect the result of the measurements. Additionally, identical patterns with a predetermined separation can be generated from two identical projectors, or a single projector with a beam splitter. Two identical projecting assemblies can exhibit identical variations, which will not introduce positioning error. Results obtained with the single projector with a beam splitter can be free from minor pattern pair difference contributions. Moreover, a dual-pattern image with known pattern separation can produce a 3D dimensioning result regardless of changes in camera focusing, distortion and magnification. Change in image position on the sensor introduced by thermal expansion may not affect the outcome, as the result is the ratio of pattern image separation to the pattern image base feature.

[0014] Potential applications of 3D optical dimensioning system include but are not limited to: object dimensioning to measure the length, width, height, volume, and irregularity, such as potential package damage in a shipment; zero contrast (surface profile only) direct product marking (DPM) barcode reading, including sensing with a mobile 3D sensor; 3D contour mapping for image recognition; and motion and gesture sensing for non-contact user interface, e.g. in electronic equipment.

[0015] Figure 1A shows a dimensioning assembly 100, according to an embodiment. The assembly 100 includes a camera module 102 having one or more image sensors and an imaging lens assembly. A first pattern generator 104 is disposed near the camera module 102, and has a first laser diode 106 (not shown) and a first pattern projection assembly 108 (not shown). A second pattern generator 110 is disposed near the camera module 102 and is spaced apart from the first pattern generator 104, and has a second laser diode 112 (not shown) and a second pattern projection assembly 114 (not shown). The first and the second pattern projection assemblies 108 and 114, respectively, are configured to generate identical patterns. A processing system 116 is configured to detect and analyze positions of elements of the generated patterns.

[0016] In an embodiment, the first and second pattern generators 104 and 110, respectively, can be equidistant from the camera module. Additionally, the first and/or second laser diode 106 and 112, respectively, can comprise a vertical-cavity surface-emitting laser. Alternatively, the first and/or second laser diode 106 and 112, respectively, can comprise an edge-emitting laser. Additionally, the first and/or second pattern projection assembly 108 and 114, respectively, can include a projection lens and a pattern die and/or a collimating lens and a diffractive optical element. The processing system 116 can be configured to detect and analyze positions of equivalent elements of the generated patterns. Additionally or alternatively, the processing system 116 can be configured to detect and analyze positions of adjacent elements of at least one of the patterns. The assembly 100 can further include one or more additional pattern generators disposed near the camera module 102.

[0017] Figure 1B shows an exemplary embodiment of a dual pattern 122 produced by the dimensioning assembly 100. Depth can be calculated based on the image separation of the same point from two identical patterns. Specifically,

$$\text{Depth} = f(s/t),$$

where s is image separation of the same point from two patterns, and t is image distance between adjacent points of the same pattern (as shown in Fig. 1B).

[0018] Figures 2A-2D schematically depict relative positions of a camera module 202 and pattern generators 204 within a dimensioning assembly, according to several embodiments. In some embodiments, the camera module 202 and two or more pattern generators 204 can be located on the same plane, whereas in other embodiments, the camera module 202 and pattern generators 204 can be located on different planes. For example, the camera module 202 can be located on one plane, and the pattern generators 204 can be located on a different plane, which can be in front of the camera module 202 (Fig. 2B), behind the camera module 202 (Fig. 2C), or a combination of those (Fig. 2A). Alternatively, the camera module 202 can be located on one plane and the pattern generators 204 can be located on one or more arcs, which can similarly be in front of the camera module 202, behind it, or both (Fig. 2D). Only two pattern generators 204 are shown in Figs. 2A-2D for illustrative purposes; some embodiments can include a different number of pattern generators 204. The figures 2A-2D show relative positions of the camera module 202 and the pattern generators 204 from the perspective of looking down from a top onto the dimensioning assembly, with the patterns being projected toward a bottom of the drawings; the horizontal lines represent mounting surfaces. Although the figures show offsetting the pattern generators 204 from the camera module 202 in the Y direction, in some embodiments they can instead, or additionally, be offset in the X and/or Z directions. Mixed configurations where the pattern generators 204 are offset in non-symmetrical ways are also possible.

[0019] Figures 3A and 3B show exemplary embodiments of an optical dimensioning system 300. According to an embodiment, the system 300 includes one or more light emitting assemblies 302 configured to project a predetermined pattern on an object. An imaging assembly 304 (not shown) is configured to sense light scattered and/or reflected of the object, and to capture an image of the object while the pattern is projected. A processing assembly 306 (not shown) is configured to analyze the image of the object to determine one or more dimension parameters of the object.

[0020] In an embodiment, the imaging assembly 304 can include one or more image sensors with an imaging lens and/or a first beam splitter 308 adapted for multi-imaging sensing, and one or more spectral filters. The one or more light emitting assemblies 302 can include a pattern generator and a second beam splitter adapted for pattern projection. Additionally, the beam splitter can include a relay lens 310 (shown in Figure 3B). Such a configuration may be used to reduce the size of the system, and can be especially beneficial for application with space limitation, such as mobile devices.

[0021] In an embodiment, the one or more dimension parameters of the object include a length, width, and/or height of the object. The system 300 can be configured for scanning a zero contrast direct product marking barcode, image recognition with 3D contour mapping, and/or motion and/or gesture sensing for non-contact user interface.

[0022] Figure 4 shows a method 400 for dual-pattern optical dimensioning, according to an embodiment. At 402, an object is illuminated with at least two identical predetermined patterns projected by one or more pattern generators. At 404, at least one image of the illuminated object is captured with a camera assembly. At 406, dimensions of the object are calculated by analyzing pattern separation of the elements comprising the projected patterns.

[0023] In an embodiment, the predetermined pattern can include a point grid. The method 400 can include controlling one or more pattern separation parameters. Additionally, illuminating an object at 402 can include illuminating an object with a projector operably coupled to a beam splitter.

Claims

1. A dimensioning assembly (100), comprising:

   a camera module (102) having one or more image sensors and an imaging lens assembly;
   a first pattern generator (104), disposed near the camera module, and having a first laser diode and a first pattern projection assembly;
   a second pattern generator (110), disposed near the camera module and spaced apart from the first pattern generator, and having a second laser diode and a second pattern projection assembly, wherein the first and the second pattern projection assemblies are configured to generate and project two identical patterns on an object; and
   a processing system configured to detect and analyze positions of elements of the generated patterns and configured to calculate a depth of the object based on a ratio of image separation (s) of an equivalent element in the two identical patterns and an image distance (t) between adjacent elements in an identical pattern of the two identical patterns.

2. The assembly according to claim 1, wherein the first and second pattern generators are equidistant from the camera module.

3. The assembly according to claim 1, wherein the first and/or second laser diode comprises a vertical-cavity surface-emitting laser.

4. The assembly according to claim 1, wherein the first and/or second laser diode comprises an edge-emitting laser.

5. The assembly according to claim 1, wherein the first and/or second pattern projection assembly includes a projection lens and a pattern die and/or a collimating lens and a diffractive optical element.

6. The assembly according to claim 1, wherein the processing system is configured to detect and analyze positions of the equivalent elements of the generated patterns.

7. The assembly according to claim 1, wherein the processing system is configured to detect and analyze positions of the adjacent elements of at least one of the patterns.

8. The assembly according to claim 1, further including one or more additional pattern generators disposed near the camera module.

9. A method (400) for dual-pattern optical dimensioning, comprising:

   illuminating (402) an object with at least two identical predetermined patterns projected by one or more pattern generators (104, 110);
   capturing (404) at least one image of the illuminated object with a camera assembly; and
   calculating (406) dimensions of the object by analyzing the projected patterns, wherein a depth of the object is calculated based on a ratio of image separation (s) of an equivalent point in the two identical predetermined patterns and an image distance (t) between adjacent points in an identical predetermined pattern of the two identical predetermined patterns.

10. The method according to claim 9, wherein the predetermined pattern includes a point grid.

11. The method according to claim 9, further including controlling one or more pattern separation parameters.

12. The method according to claim 9, wherein illuminating an object includes illuminating an object with a projector operably coupled to a beam splitter.

Patentansprüche

1. Abmessungsbestimmungsanordnung (100), die Folgendes umfasst:

   ein Kameramodul (102), das einen oder mehrere Bildsensoren und eine Abbildungslinsen-Anordnung aufweist;
   einen ersten Mustergenerator (104), der in der Nähe des Kameramoduls angeordnet ist und eine erste Laserdiode und eine erste Musterprojektionsanordnung aufweist;
   einen zweiten Mustergenerator (110), der in der Nähe des Kameramoduls angeordnet ist, von dem ersten Mustergenerator beabstandet ist und eine zweite Laserdiode und eine zweite Musterprojektionsanordnung aufweist, wobei die erste und die zweite Musterprojektionsanordnung konfiguriert sind, zwei identische Muster zu erzeugen und auf ein Objekt zu projizieren; und
   ein Verarbeitungssystem, das konfiguriert ist, Positionen von Elementen der erzeugten Muster zu detektieren und zu analysieren, und das konfiguriert ist, eine Tiefe des Objekts basierend auf einem Verhältnis von Bildtrennung (s) eines äquivalenten Elements in den zwei identischen Mustern und einem Bildabstand (t) zwischen benachbarten Elementen in einem identischen Muster der zwei identischen Muster zu berechnen.

2. Anordnung nach Anspruch 1, wobei der erste und der zweite Mustergenerator von dem Kameramodul gleich weit entfernt sind.

3. Anordnung nach Anspruch 1, wobei die erste und/oder zweite Laserdiode eine oberflächenemittierende Laserdiode umfassen.

4. Anordnung nach Anspruch 1, wobei die erste und/oder zweite Laserdiode eine kantenemittierende Laserdiode umfassen.

5. Anordnung nach Anspruch 1, wobei die erste und/oder zweite Musterprojektionsanordnung eine Projektionslinse und ein Musterplättchen und/oder eine Kollimatorlinse und ein beugendes optisches Element enthalten.

6. Anordnung nach Anspruch 1, wobei das Verarbeitungssystem konfiguriert ist, Positionen der äquivalenten Elemente der erzeugten Muster zu detektieren und zu analysieren.

7. Anordnung nach Anspruch 1, wobei das Verarbeitungssystem konfiguriert ist, Positionen der benachbarten Elemente von mindestens einem der Muster zu detektieren und zu analysieren.

8. Anordnung nach Anspruch 1, die ferner einen oder mehrere zusätzliche Mustergeneratoren, die in der Nähe des Kameramoduls angeordnet sind, enthält.

9. Verfahren (400) zum optischen Bestimmen von Abmessungen mit Doppelmuster, das Folgendes umfasst:

Beleuchten (402) eines Objekts mit mindestens zwei identischen vorbestimmten Mustern, die von einem oder mehreren Mustergeneratoren (104, 110) erzeugt werden;
Erfassen (404) mindestens eines Bildes des beleuchteten Objekts mit einer Kameraanordnung; und
Berechnen (406) von Abmessungen des Objekts durch Analysieren der projizierten Muster, wobei eine Tiefe des Objekts basierend auf einem Verhältnis der Bildtrennung (s) eines äquivalenten Punktes in den zwei identischen vorbestimmten Mustern und einem Bildabstand (t) zwischen benachbarten Punkten in einem identischen vorbestimmten Muster der zwei identischen vorbestimmten Mustern berechnet wird.

10. Verfahren nach Anspruch 9, wobei das vorbestimmte Muster ein Punktgitter enthält.

11. Verfahren nach Anspruch 9, das ferner das Steuern eines oder mehrerer Mustertrennungsparameter enthält.

12. Verfahren nach Anspruch 9, wobei das Beleuchten eines Objekts das Beleuchten eines Objekts mit einem Projektor, der betriebstechnisch an einen Strahlteiler gekoppelt ist, enthält.

Revendications

1. Ensemble de dimensionnement (100), comprenant :

un module de caméra (102) comportant un ou plusieurs capteurs d'image et un ensemble d'objectif d'imagerie ;
un premier générateur de motif (104), disposé près du module de caméra, et comportant une première diode laser et un premier ensemble de projection de motif ;
un second générateur de motif (110), disposé près du module de caméra et espacé du premier générateur de motif, et comportant une seconde diode laser et un second ensemble de projection de motif, dans lequel les premier et second ensembles de projection de motif sont configurés pour générer et projeter des motifs identiques sur un objet ; et
un système de traitement configuré pour détecter et analyser des positions d'éléments des motifs générés et configuré pour calculer une profondeur de l'objet en fonction d'un rapport de séparation(s) d'image d'un élément équivalent dans les deux motifs identiques et d'une distance d'image (t) entre des éléments adjacents dans un motif identique des deux motifs identiques.

2. Ensemble selon la revendication 1, dans lequel les premier et second générateurs de motif sont équidistants par rapport au module de caméra.

3. Ensemble selon la revendication 1, dans lequel la première et/ou seconde diode laser comprennent un laser à émission de surface à cavité verticale.

4. Ensemble selon la revendication 1, dans lequel la première et/ou seconde diode laser comprennent un laser à émission par le bord.

5. Ensemble selon la revendication 1, dans lequel le premier et/ou second ensemble de projection de motif comportent un objectif de projection et une matrice de motif et/ou une lentille collimatrice et un élément optique de diffraction.

6. Ensemble selon la revendication 1, dans lequel le système de traitement est configuré pour détecter et analyser des positions des éléments équivalents des motifs générés.

7. Ensemble selon la revendication 1, dans lequel le système de traitement est configuré pour détecter et analyser des positions des éléments adjacents d'au moins un des motifs.

8. Ensemble selon la revendication 1, comportant en outre un ou plusieurs générateurs de motif supplémentaires disposés près du module de caméra.

9. Procédé (400) de dimensionnement optique à double motif, comprenant :

l'éclairage (402) d'un objet avec au moins deux motifs prédéterminés identiques projetés par un ou plusieurs générateurs de motif (104, 110) ;
la capture (404) d'au moins une image de l'objet éclairé avec un ensemble de caméra ; et
le calcul (406) de dimensions de l'objet en analysant les motifs projetés, dans lequel une profondeur de l'objet est calculée en fonction d'un rapport de séparation(s) d'image d'un élément équivalent dans les deux motifs identiques et d'une distance d'image (t) entre des éléments adjacents dans un motif identique des deux motifs identiques.

10. Procédé selon la revendication 9, dans lequel le motif prédéterminé comporte une grille de points.

11. Procédé selon la revendication 9, comportant en outre la commande d'un ou de plusieurs paramètres de séparation de motif.

12. Procédé selon la revendication 9, dans lequel l'éclairage d'un objet comporte l'éclairage d'un objet avec un projecteur couplé opérationnellement à un diviseur de faisceau.

FIG. 1A

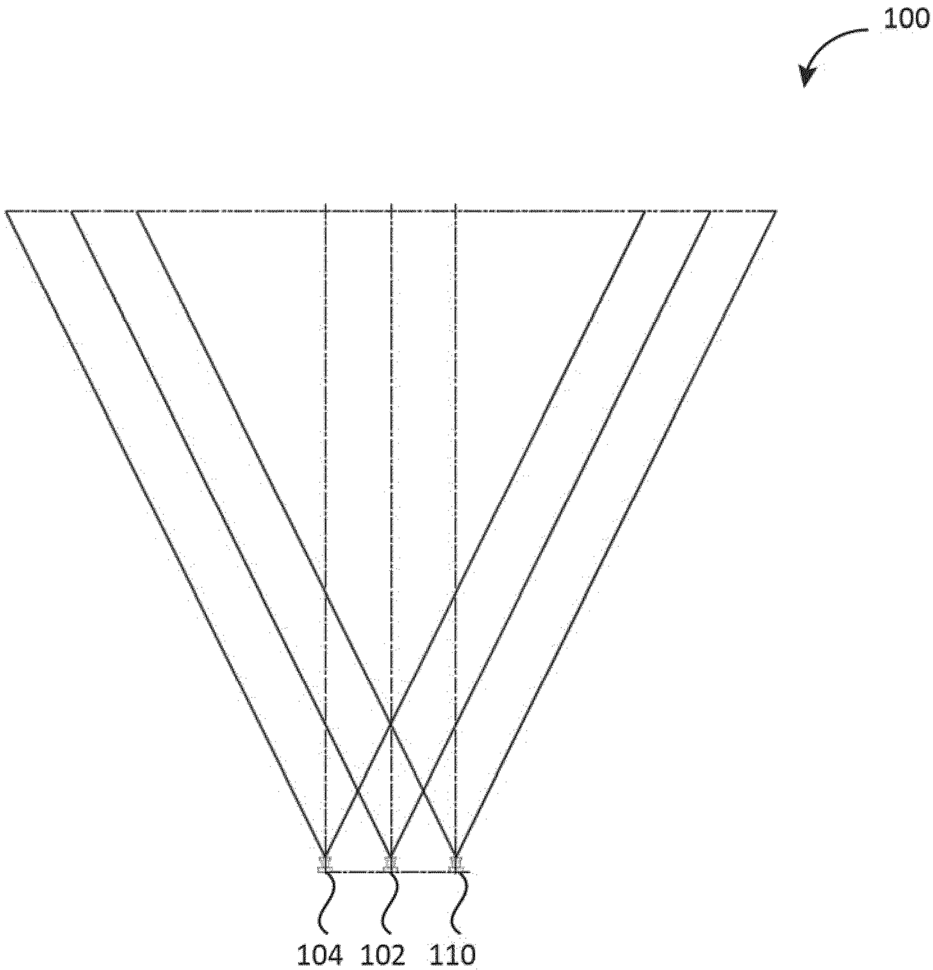


FIG. 1B

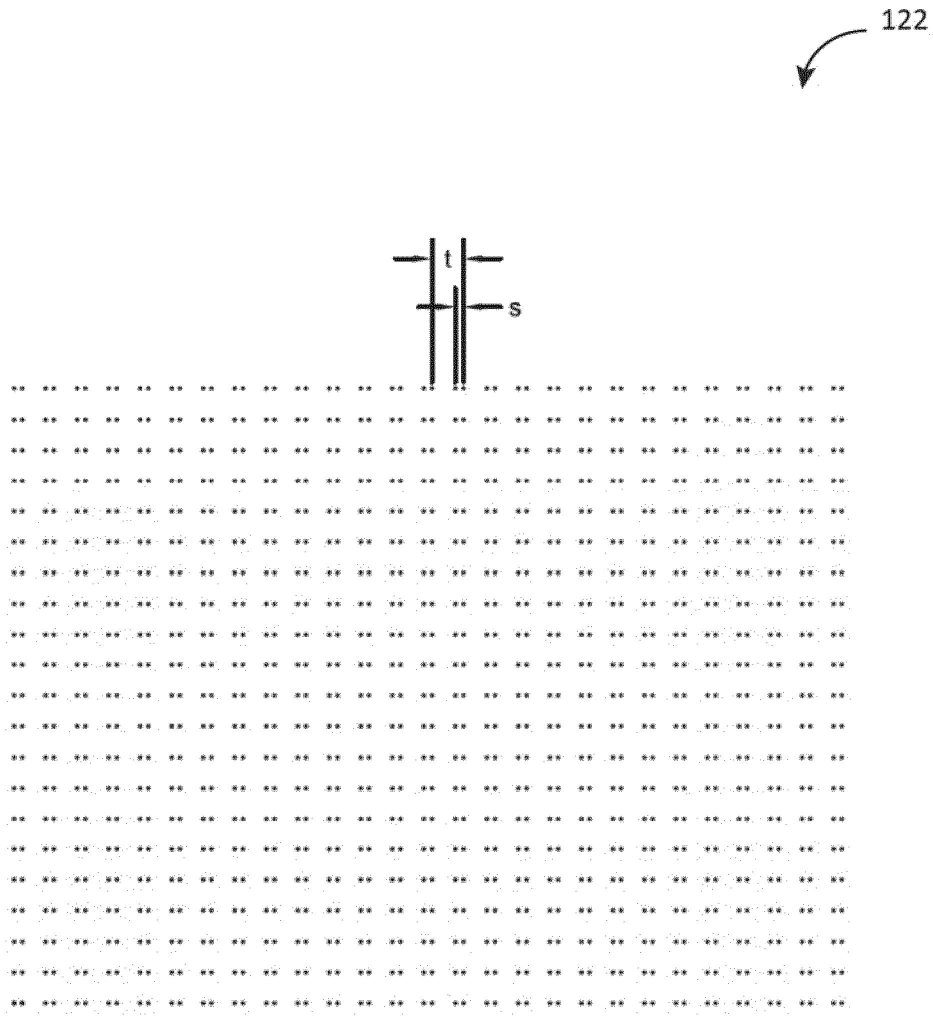


FIG. 2A

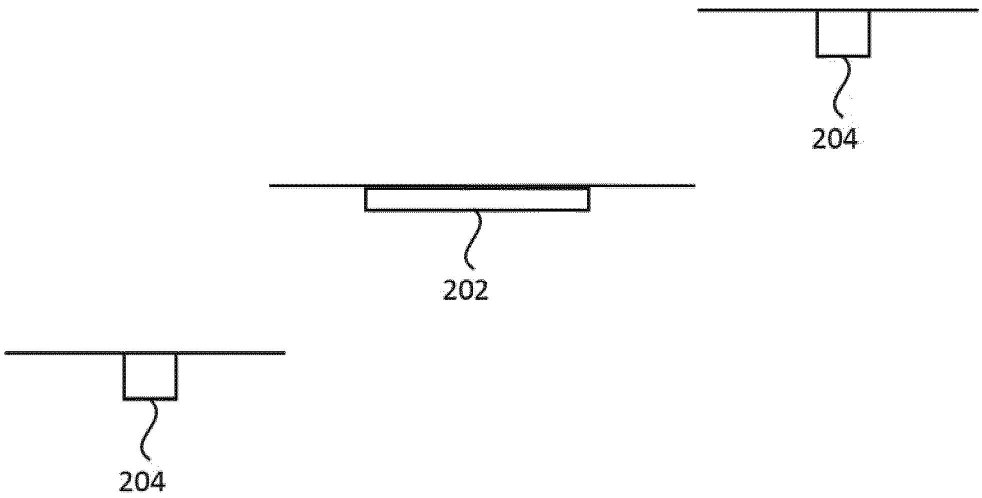


FIG. 2B

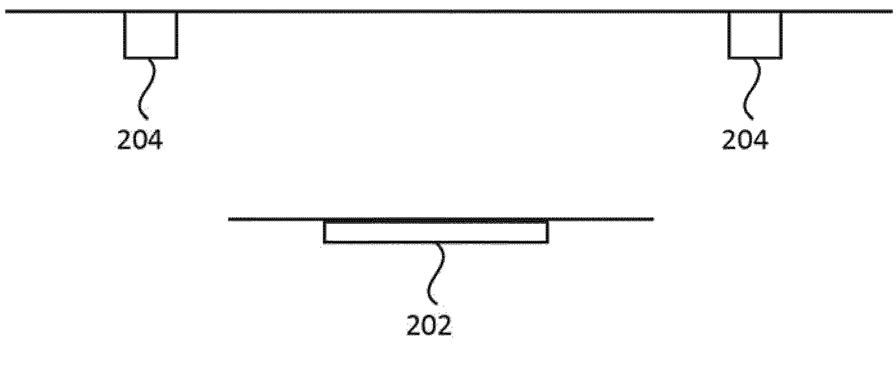


FIG. 2C

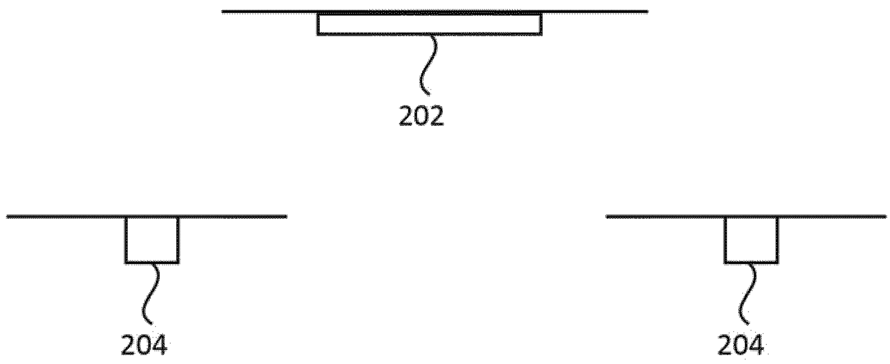


FIG. 2D

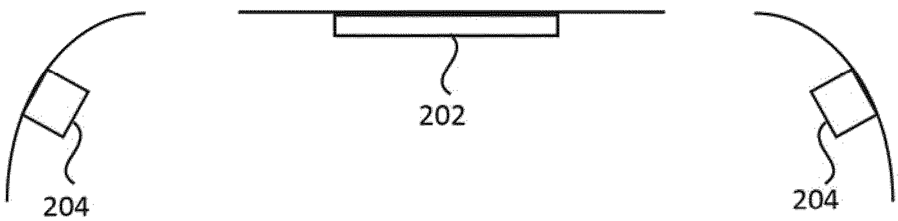


FIG. 3A

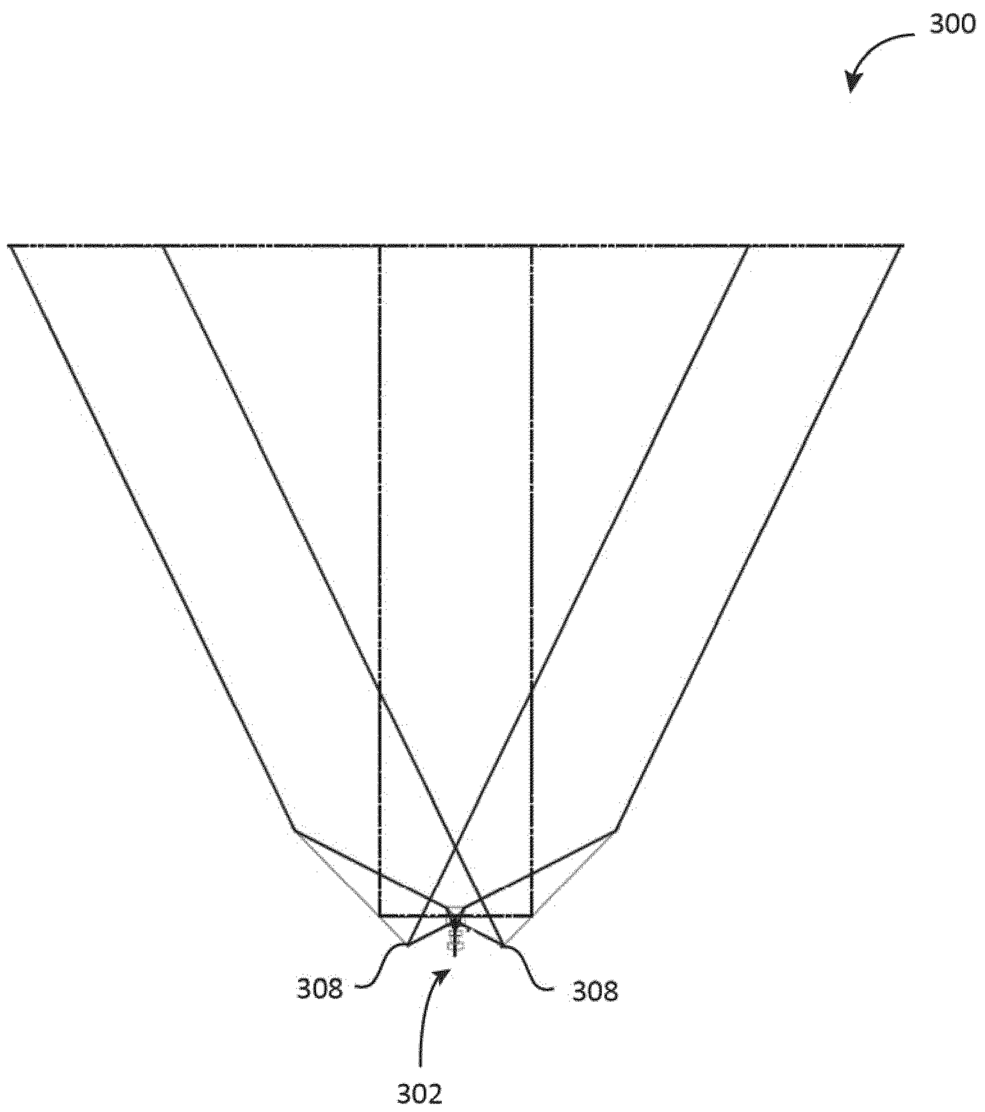


FIG. 3B

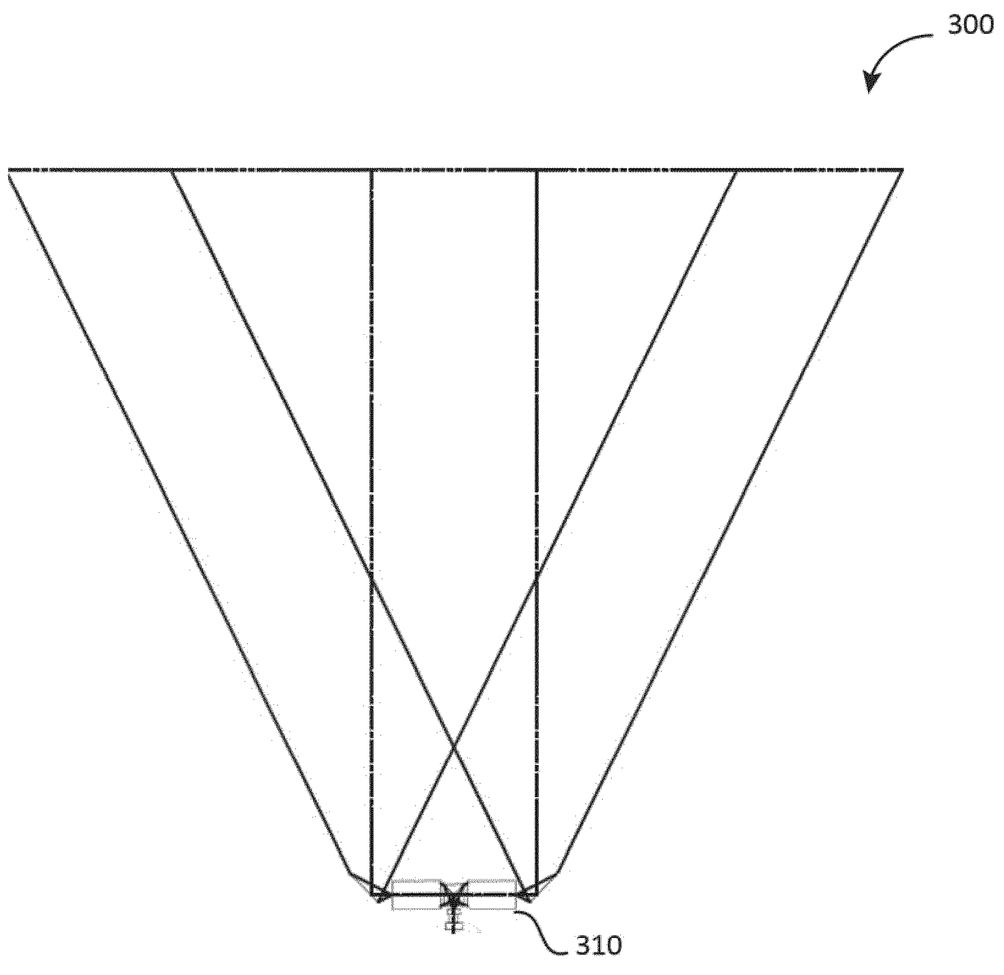
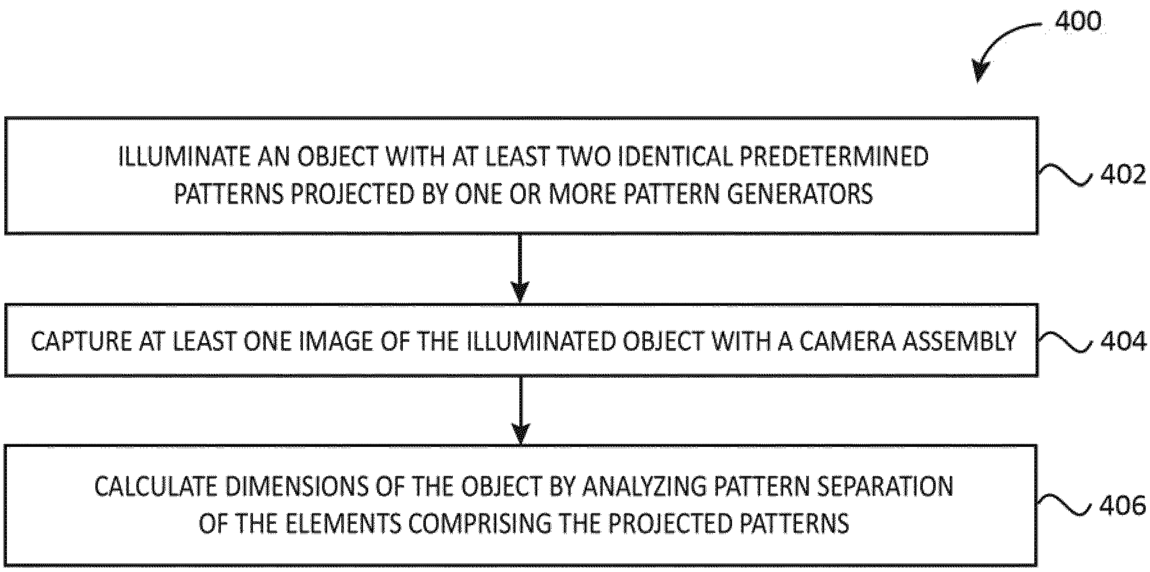


FIG. 4


400
ILLUMINATE AN OBJECT WITH AT LEAST TWO IDENTICAL PREDETERMINED PATTERNS PROJECTED BY ONE OR MORE PATTERN GENERATORS
402
CAPTURE AT LEAST ONE IMAGE OF THE ILLUMINATED OBJECT WITH A CAMERA ASSEMBLY
404
CALCULATE DIMENSIONS OF THE OBJECT BY ANALYZING PATTERN SEPARATION OF THE ELEMENTS COMPRISING THE PROJECTED PATTERNS
406

REFERENCES CITED IN THE DESCRIPTION

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- CN 104050656 A **[0004]**
- US 20150267701 A1 **[0004]**
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