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(54) Title: DISTANCE SENSOR

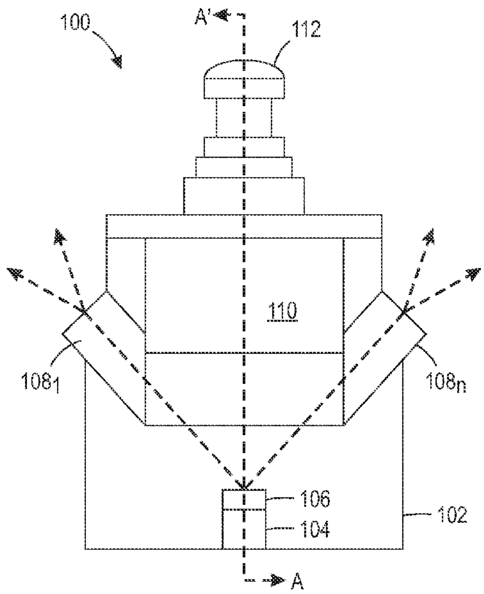

FIG. 1A

(57) Abstract: In one embodiment, a distance sensor includes an image capturing device positioned to capture an image of a field of view and a first plurality of projection points arranged around a first lens of the image capturing device, wherein each projection point of the first plurality of projection points is configured to emit a plurality of projection beams in different directions within the field of view.

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DISTANCE SENSOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of United States Provisional Patent Application Serial No. 62/068,250, filed October 24, 2014 and United States Provisional Patent Application Serial No. 62/159,286, filed May 10, 2015. Both of these applications are herein incorporated by reference in their entireties.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates generally computer vision systems and relates more particularly to sensors for measuring the distance between a vehicle and an object or point in space.

[0003] Unmanned vehicles, such as robotic vehicles and drones, typically rely on computer vision systems for obstacle detection and navigation in the surrounding environment. These computer vision systems, in turn, typically rely on various sensors that acquire visual data from the surrounding environment, which the computer vision systems process in order to gather information about the surrounding environment. For instance, data acquired via one or more imaging sensors may be used to determine the distance from the vehicle to a particular object or point in the surrounding environment.

SUMMARY

[0004] In one embodiment, a distance sensor includes an image capturing device positioned to capture an image of a field of view and a first plurality of projection points arranged around a first lens of the image capturing device, wherein each projection point of the first plurality of projection points is configured to emit a plurality of projection beams in different directions within the field of view.

[0005] In another embodiment, a method for calculating a distance to an object includes projecting a plurality of projection beams from each of a plurality of projection points, wherein the plurality of projection points is arranged around a lens of an image capturing device, and wherein each beam of the plurality of projection beams is directed in a different direction within a field of view, capturing an image

of the field of view, wherein the object is visible in the image and a projection patterns generated by the plurality of projection beams is also visible in the image, and calculating the distance to the object using information in the image.

[0006] In another embodiment, a computer-readable storage device stores a plurality of instructions which, when executed by a processor, cause the processor to perform operations for calculating a distance to an object. The operations include projecting a plurality of projection beams from each of a plurality of projection points, wherein the plurality of projection points is arranged around a lens of an image capturing device, and wherein each beam of the plurality of projection beams is directed in a different direction within a field of view, capturing an image of the field of view, wherein the object is visible in the image and a projection patterns generated by the plurality of projection beams is also visible in the image, and calculating the distance to the object using information in the image.

[0007] In another embodiment, a method for calculating a distance to an object includes projecting a plurality of points of light onto a field of view, from a plurality of projection points, capturing an image of the field of view, wherein the object is visible in the image and a projection pattern formed by the plurality of points of light is also visible in the image, and calculating the distance to the object in accordance with a positional relationship between at least two of the plurality of points of light, wherein the at least two of the plurality of points of light are emitted by at least two different projection points of the plurality of projection points.

[0008] In another embodiment, a computer-readable storage device stores a plurality of instructions which, when executed by a processor of a server, cause the processor to perform operations for calculating a distance to an object. The operations include projecting a plurality of points of light onto a field of view, from a plurality of projection points, capturing an image of the field of view, wherein the object is visible in the image and a projection pattern formed by the plurality of points of light is also visible in the image, and calculating the distance to the object in accordance with a positional relationship between at least two of the plurality of points of light, wherein the at least two of the plurality of points of light are emitted by at least two different projection points of the plurality of projection points.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The teaching of the present disclosure can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

[0010] FIG. 1A illustrates a cross-sectional view of one embodiment of a distance sensor of the present disclosure;

[0011] FIG. 1B illustrates a top view of the distance sensor of FIG. 1A;

[0012] FIG. 2 illustrates an example field of view of the distance sensor of FIGs. 1A and 1B;

[0013] FIG. 3 illustrates one embodiment of a distance sensor having a field of view of approximately 360 degrees;

[0014] FIG. 4 illustrates a flowchart of a method for calculating the distance from a sensor to an object or point in space;

[0015] FIG. 5 illustrates a triangulation technique by which the distance from a sensor to an object or point may be calculated;

[0016] FIG. 6 depicts a high-level block diagram of a general-purpose computer suitable for use in performing the functions described herein;

[0017] FIG 7A illustrates one simplified example of a distance sensor that is configured to project ring-shaped patterns;

[0018] FIG. 7B illustrates a more three-dimensional view of the projection pattern that may be emitted by the distance sensor of FIG. 7A;

[0019] FIG. 7C illustrates another view of the distance sensor of FIG. 7A in which the concept of tilt angle is visible;

[0020] FIGs. 8A and 8B illustrate the concepts from which a simple algorithm for calculating the distance to an object using the sensor of FIGs. 7A-7C can be derived;

[0021] FIG. 9 illustrates the concepts of FIGs. 8A-8B extended to an example distance sensor;

[0022] FIGs. 10A and 10B illustrate another embodiment of a distance sensor of the present disclosure; nd

[0023] FIGs. 11A and 11B illustrate another embodiment of a distance sensor of the present disclosure.

[0024] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

[0025] In one embodiment, the present disclosure relates to a distance sensor. Distance sensors may be used in unmanned vehicles in order to help a computer vision system determine the distance from the vehicle to a particular object or point in the surrounding environment. For instance, a distance sensor may project one or more beams of light onto the object or point and then compute the distance according to time of flight (TOF), analysis of the reflected light (e.g., lidar), or other means. Conventional distance sensors of this type tend to be bulky, however, and thus may not be suitable for use in compact vehicles. Moreover, the sensors can be very expensive to manufacture and tend to have a limited field of view. For instance, even using an arrangement of multiple conventional imaging sensors provides a field of view that is less than 360 degrees.

[0026] Embodiments of the disclosure provide a compact distance sensor that is economical to manufacture, includes few or no moving parts, and can measure distances in a field of view of up to 360 degrees. In one embodiment, the sensor uses a set of beam splitting means such as an array of diffractive optical elements (DOEs) to generate a plurality of projection points around a wide angle lens. Each of the plurality of projection points emits a plurality of beams into a field of view. From the appearances of the beams, the sensor can measure distances in a 180 degree hemispherical field of view. By mounting two such sensors back-to-back, distances can be measured in a 360 degree field of view. The DOEs make it possible to split a beam generated by a single light source (e.g., laser) into multiple projection beams that are projected onto an object or point in the field of view. However, in other embodiments, beams emitted by multiple light sources are split by the DOEs. The distance from the sensor to the object or point can then be calculated in one cycle of projection and image capture from the multiple projections.

[0027] FIGs. 1A and 1B illustrate one embodiment of a distance sensor 100 of the present disclosure. In particular, FIG. 1A illustrates a cross-sectional view of the distance sensor 100, while FIG. 1B illustrates a top view of the distance sensor 100 of FIG. 1A. The distance sensor 100 may be mounted, for example, to an unmanned vehicle.

[0028] As illustrated in FIG. 1A, the distance sensor 100 comprises a plurality of components arranged within a compact housing 102. The components include at least one light source 104, a first beam splitting means, hereinafter referred to as a first diffractive optical element 106, an array of second beam splitting means, hereinafter referred to as second diffractive optical elements 108_1-108_n (and hereinafter collectively referred to as "second diffractive optical elements 108"), and an imaging sensor 110 including a wide-angle lens 112.

[0029] The components are arranged substantially symmetrically about a central axis A-A'. In one embodiment, the central axis A-A' coincides with the optical axis of the imaging sensor 110. In one embodiment, the light source 104 is positioned at a first end of the central axis A-A'. In one embodiment, the light source 104 is a laser light source that emits a single beam of light along the central axis A-A'. Hereinafter, the single beam emitted by the light source 104 may also be referred to as the "primary beam." In one embodiment, the light source 104 emits light of a wavelength that is known to be relatively safe to human vision (e.g., infrared). In a further embodiment, the light source 104 may include circuitry to adjust the intensity of its output. In a further embodiment, the light source 104 may emit light in pulses, so as to mitigate the effects of ambient light on image capture.

[0030] The first diffractive optical element (DOE) 106 is positioned along the central axis A-A' in proximity to the light source 104 (e.g., "in front" of the light source 104, relative to the direction in which light emitted by the light source 104 propagates). In particular, the first DOE 106 is positioned to intercept the single beam of light emitted by the light source 104 and to split the single or primary beam into a plurality of secondary beams. In one embodiment, the angles between the central axis A-A' and each of the secondary beams are equal. The first DOE 106 is any optical component that is capable of splitting the primary beam into a plurality of secondary beams that diverge from the primary beam in different directions. For example, in one embodiment, the first DOE 106 may include a conical mirror or holographic film. In this case, the plurality of secondary beams are arranged in a cone shape. In further embodiments, the primary beam may be split by means other than diffraction.

[0031] The array of second DOEs 108 is positioned along the central axis A-A' in proximity to the first DOE 106 (e.g., "in front" of the first DOE 106, relative to the direction in which light emitted by the light source 104 propagates). In particular, the array of second DOEs 108 is positioned such that the first DOE 106 is positioned between the light source 104 and the array of second DOEs 108. As more clearly illustrated in FIG. 1B, in one embodiment, the second DOEs 108 are arranged in a ring-shaped array, with the central axis A-A' passing through the center of the ring and the second DOEs 108 spaced at regular intervals around the ring. For instance, in one embodiment, the second DOEs 108 are spaced approximately thirty degrees apart around the ring. In one embodiment, the array of second DOES 108 is positioned "behind" a principal point of the imaging sensor 110 (i.e., the point where the optical axis A—A' intersects the image plane), relative to the direction in which light emitted by the light source 104 propagates.

[0032] Each second DOE 108 is positioned to intercept one of the secondary beams produced by the first DOE106 and to split the secondary beam into a plurality of (e.g., two or more) tertiary beams that are directed away from the second DOE 108 in a radial manner. Thus, each second DOE 108 defines a projection point of the sensor 100 from which a group of projection beams (or tertiary beams) is emitted into the field of view. In one embodiment, each respective plurality of tertiary beams fans out to cover a range of approximately one hundred degrees. The second DOEs 108 are any optical components that are capable of splitting a respective secondary beam into a plurality of tertiary beams that diverge from the secondary beam in different directions. For example, in one embodiment, each second DOE may include a conical mirror or holographic film. In other embodiments, however, the secondary beams are split by a means other than diffraction.

[0033] In one embodiment, each plurality of tertiary beams is arranged in a fan or radial pattern, with equal angles between each of the beams. In one embodiment, each of the second DOEs 108 is configured to project tertiary beams that create a different visual pattern on a surface. For example, one second DOE

108 may project a pattern of dots, while another second DOE 108 may project a pattern of lines or x's.

[0034] The imaging sensor 110 is positioned along the central axis A'A', in the middle of the array of second DOEs 108 (e.g., at least partially "in front" of the array of second DOEs 108, relative to the direction in which light emitted by the light source 104 propagates). In one embodiment, the imaging sensor 110 is an image capturing device, such as a still or video camera. As discussed above, the imaging sensor 110 includes a wide-angle lens, such as a fisheye lens, that creates a hemispherical field of view. In one embodiment, the imaging sensor 110 includes circuitry for calculating the distance from the distance sensor 100 to an object or point. In another embodiment, the imaging sensor includes a network interface for communicating captured images over a network to a processor, where the processor calculates the distance from the distance sensor 100 to an object or point and then communicates the calculated distance back to the distance sensor 100.

[0035] Thus, in one embodiment, the distance sensor 100 uses a single light source (e.g., light source 104) to produce multiple projection points from which sets of projection beams (e.g., comprising patterns of dots or lines) are emitted. The distance from the distance sensor 100 to an object can be calculated from the appearances of the projection beams in the field of view (as discussed in greater detail below). In particular, the use of the first and second DOEs makes it possible to generate a plurality of projection points around the lens, from the single beam of light emitted by the light source. This allows the distance sensor 100 maintain a relatively compact form factor while measuring distance within a wide field of view. The imaging sensor 110 and the light source 104 can also be mounted in the same plane in order to make the design more compact; however, in one embodiment, the second DOEs 108_1-108_n are positioned behind the principal point of the imaging sensor 110 in order to increase the field of view that can be covered by the projection beams (e.g., such that the depth angle of the field of view is closer to a full 180 degrees, or, in some cases, even greater).

[0036] Moreover, since each of the second DOEs 108 projects tertiary beams of a different pattern, the circuitry in the imaging sensor can easily determine which beams in a captured image were created by which of the second DOEs 108. This facilitates the distance calculations, as discussed in greater detail below.

[0037] Although the sensor 100 is illustrated as including only a single light source 104 (which reduces the total number of components in the sensor 100), in alternative embodiments, the sensor may include a plurality of light sources. In this case, the first DOE 106 may not be necessary. Instead, in one embodiment, each light source of the plurality of light sources may correspond to one DOE in an array of DOEs (such as the array of second DOEs 108 in Figure 1A and Figure 1B). Notably, this configuration still produces a plurality of projection points (e.g., one projection point defined by each DOE in the array) around the imaging sensor's lens and from which sets of projection beams may be emitted.

[0038] FIG. 2 illustrates an example field of view 200 of the distance sensor 100 of FIGs. 1A and 1B. In FIG. 2, certain components of the distance sensor 100 are also illustrated in an exploded view. As shown, the field of view 200 is substantially hemispherical in shape. Furthermore, the plurality of tertiary light beams produced by the distance sensor 100 projects a pattern of light onto the "virtual" hemisphere. The patterns are represented by the series of concentric circles that are illustrated where each tertiary beam meets the hemisphere. The circles are depicted as gradually decreasing in size as the distance from the distance sensor 100 increases, in order to show how the patterns created by the tertiary beams change visually by object distance.

[0039] As shown in FIG. 2, the field of view of the distance sensor 100 covers approximately 180 degrees. In one embodiment, the field of view can be expanded to approximately 360 degrees by mounting two distance sensors back-to-back.

[0040] FIG. 3, for example, illustrates one embodiment of a distance sensor 300 having a field of view of approximately 360 degrees. The distance sensor 300 in fact comprises two distance sensors 302_1 and 302_2 that are configured similarly to the distance sensor 100 of Figures 1A and 1B, but are mounted in a back-to-back arrangement, i.e., such that the respective light sources 304_1 and 304_2 of the two distance sensors 302_1 and 302_2 are adjacent, but project their primary beams in opposite directions (i.e., a difference of 180 degrees exists between the two primary beams).

[0041] As illustrated, the two distance sensors 302_1 and 302_2 may be configured substantially similarly to the distance sensors 100 of FIGs. 1A and 1B. Thus, each distance sensor 302_1 and 302_2 includes a respective light source 304_1

and 304_2, a respective imaging sensor 306_1 and 306_2, a respective wide-angle lens 308_1 and 308_2, a respective first DOE 310_1 and 310_2, and a respective circular array of second DOEs 312_{11}-312_{1n} and 312_{21}-312_{2n}. However, the imaging sensors 306_1 or 306_2 may share circuitry or a network interface for calculating the distance from the distance sensor 300 to an object or point.

[0042] Notably, the second DOEs 312_{11}-312_{1n} and 312_{21}-312_{2n} are positioned behind the principal points of their respective imaging sensors 306_1 and 306_2 in this embodiment. This relative positioning of the imaging sensors 306_1 and 306_2 (and especially the lenses 308_1 and 308_2) and second DOEs 312_{11}-312_{1n} and 312_{21}-312_{2n} allows the beam patterns projected by the distance sensor 300 to cover a larger field of view (e.g., closer to a full 180 degrees for each distance sensor 302_1 and 302_2, or closer to a full 360 degrees for the sensor 300 as a whole).

[0043] FIG. 4 illustrates a flowchart of a method 400 for calculating the distance from a sensor to an object or point in space. In one embodiment, the method 400 may be performed by a processor integrated in an imaging sensor (such as the imaging sensor 110 illustrated in FIG. 1A) or a general purpose computing device as illustrated in FIG. 5 and discussed below.

[0044] The method 400 begins in step 402. In step 404, a light source is activated to generate a primary beam of light. In one embodiment, a single primary beam is generated by a single light source; however, in other embodiments, multiple primary beams are generated by multiple light sources. In one embodiment, the light source or light sources comprise a laser light source.

[0045] In optional step 406, the primary beam is split into a plurality of secondary beams using a first beam splitting means (e.g., a diffractive optical element) that is positioned in the path along which the primary beam propagates. The first beam splitting means may be, for example, a conical mirror. Step 406 is performed, for example, when the distance sensor (of which the imaging sensor is a part) includes only a single light source.

[0046] In step 408, each beam in the plurality of secondary beams is split into a plurality of projection or tertiary beams using a second beam splitting means (e.g., second diffractive optical element) in an array of beam splitting means. In one embodiment, a plurality of second beam splitting means are positioned in a ring, such that each second beam splitting means is positioned in the path along which one of the secondary beams propagates. In one embodiment, at least some of the second beam splitting means are conical mirrors. In one embodiment, where the distance sensor comprises a plurality of light sources, the method 400 may proceed directly from step 404 to step 408. In this case, each primary beam of a plurality of primary beams (generated using the plurality of light sources) is directly split into a plurality of projection beams by one of the second beam splitting means.

[0047] In step 410, at least one image of the object or point is captured. The image includes a pattern that is projected onto the object or point and onto the surrounding space. The pattern is created by each of the projection beams projecting a series of dots, lines, or other shapes onto the object, point, or surrounding space.

[0048] In step 412, the distance from the sensor to the object or point is calculated using information from the images captured in step 410. In one embodiment, a triangulation technique is used to calculate the distance. For example, the positional relationships between parts of the patterns projected by the sensor can be used as the basis for the calculation.

[0049] The method 400 ends in step 414. Thus, the method 400, in combination with the sensor depicted in FIGs. 1A-1B or in FIG. 3, can measure the distance from the sensor to an object or point in space in a single cycle of image capture and calculation.

[0050] FIG. 5, for example, illustrates a triangulation technique by which the distance from the sensor to the object or point may be calculated in step 412. In particular, FIG. 5 illustrates the example imaging sensor 110 of FIG. 1, as well as two of the projection points, which may be defined by two of the second diffractive optical elements 108_1 and 108_2. The projection points are spaced equal distances, x, from the imaging sensor 110, such that there is a distance of s between the two projection points (e.g., x = s/2). Each of the projection points emits a respective projection beam 500_1 and 500_2, which is incident upon the object to create a respective point 502_1 and 502_2 (e.g., dot or line) in a pattern. These points 502_1 and 502_2 are detected by the imaging sensor 110 and may be used to calculate the distance, D, between the imaging sensor 110 and the object as follows:

$$D = s/(-\tan\alpha_2 + \tan\alpha_1 + \tan\theta_2 + \tan\theta_1) \qquad \text{(EQN. 1)}$$

where α_2 is the angle formed between the projection beam 500_2 and a central axis c_2 of the second diffractive optical element 108_2, α_1 is the angle formed between the projection beam 500_1 and a central axis c_1 of the second diffractive optical element 108_1, θ_2 is the angle formed between the central optical axis O of the imaging sensor 110 and the angle at which the imaging sensor 110 perceives the point 502_2 created by the projection beam 500_2, and θ_1 is the angle formed between the central optical axis O of the imaging sensor 110 and the angle at which the imaging sensor 110 perceives the point 502_1 created by the projection beam 500_1.

[0051] EQN. 1 is derived from the following relationships:

$$D^* \tan\alpha_1 + D * \tan\theta_1 = x \qquad \text{(EQN. 2)}$$

$$D^* \tan\alpha_2 + D * \tan\theta_2 = s\text{-}x \qquad \text{(EQN. 3)}$$

[0052] EQNs. 2 and 3 allow one to calculate the distance from a source of a projection pattern (comprising, e.g., a pattern of dots) to an object onto which the projection pattern is projected. The distance is calculated based on the positional relationship between the points of light (e.g., the dots) that form the projection pattern when the points of light are emitted by different projection points around the source. In this embodiment, the positional relationships between the points of light are known a priori (i.e., not measured as part of the calculation).

[0053] FIG. 6 depicts a high-level block diagram of a general-purpose computer suitable for use in performing the functions described herein. As depicted in FIG. 6, the system 600 comprises one or more hardware processor elements 602 (e.g., a central processing unit (CPU), a microprocessor, or a multi-core processor), a memory 604, e.g., random access memory (RAM) and/or read only memory (ROM), a module 605 for calculating distance, and various input/output devices 606 (e.g., storage devices, including but not limited to, a tape drive, a floppy drive, a hard disk drive or a compact disk drive, a receiver, a transmitter, a lens and optics, an output port, an input port and a user input device (such as a keyboard, a keypad, a mouse, a microphone and the like)). Although only one processor element is shown, it should be noted that the general-purpose computer may employ a plurality of processor elements. Furthermore, although only one general-purpose computer is shown in the figure, if the method(s) as discussed above is implemented in a distributed or parallel manner for a particular illustrative example, i.e., the steps of the above method(s) or the entire method(s) are implemented across multiple or parallel general-purpose computers, then the general-purpose computer of this figure is intended to represent each of those multiple general-purpose computers. Furthermore, one or more hardware processors can be utilized in supporting a virtualized or shared computing environment. The virtualized computing environment may support one or more virtual machines representing computers, servers, or other computing devices. In such virtualized virtual machines, hardware components such as hardware processors and computer-readable storage devices may be virtualized or logically represented.

[0054] It should be noted that the present disclosure can be implemented in software and/or in a combination of software and hardware, e.g., using application specific integrated circuits (ASIC), a programmable logic array (PLA), including a field-programmable gate array (FPGA), or a state machine deployed on a hardware device, a general purpose computer or any other hardware equivalents, e.g., computer readable instructions pertaining to the method(s) discussed above can be used to configure a hardware processor to perform the steps, functions and/or operations of the above disclosed methods. In one embodiment, instructions and data for the present module or process 605 for calculating distance (e.g., a software program comprising computer-executable instructions) can be loaded into memory 604 and executed by hardware processor element 602 to implement the steps, functions or operations as discussed above in connection with the example method 400. Furthermore, when a hardware processor executes instructions to perform "operations", this could include the hardware processor performing the operations directly and/or facilitating, directing, or cooperating with another hardware device or component (e.g., a co-processor and the like) to perform the operations.

[0055] The processor executing the computer readable or software instructions relating to the above described method(s) can be perceived as a programmed processor or a specialized processor. As such, the present module 605 for calculating distance (including associated data structures) of the present disclosure can be stored on a tangible or physical (broadly non-transitory) computer-readable storage device or medium, e.g., volatile memory, non-volatile memory, ROM memory, RAM memory, magnetic or optical drive, device or diskette and the like. More specifically, the computer-readable storage device may comprise any physical devices that provide the ability to store information such as data and/or instructions to be accessed by a processor or a computing device such as a computer or an application server.

[0056] As discussed above, the set of projection points, for example as defined by beam splitting means such as diffractive optical elements (DOEs), can be configured to project a variety of patterns onto a field of view. For instance, the shapes of the individual points of light of a projected pattern may vary (e.g., the points of light may comprise dots, lines, etc.). In addition, the individual points of light may collectively form a variety of patterns, including a ring-shaped pattern, a spherical pattern, a pattern of parallel lines or planes, or a triangular pattern, among other potential patterns. In other words, groups of individual points of light can form a line or lines with ordinality (e.g., for projection patternss having spherical or triangular shapes or patterns of parallel lines or planes). In one embodiment, the ordinality between individual points of light is the same or shares similar characteristics (e.g., symmetry, rotational accordance, partial accordance, etc.). Furthermore, groups of individual points of light can form dots with ordinality (e.g., for projection patterns having ring shapes). In one embodiment, the ordinality between individual points of light is the same or shares similar characteristics (e.g., differences in dot shape, interval relationships, etc.).

[0057] FIG 7A illustrates one simplified example of a distance sensor 700 that is configured to project ring-shaped patterns. The optical axis of the distance sensor 700 is indicated by the line A—A' and the principal point 702 of the imaging sensor 710 (i.e., the point where the optical axis A—A' intersects the image plane). In one embodiment, a ring of beam splitting means 704_1-704_n (hereinafter collectively referred to as "beam splitting means 704") is positioned behind the principal point 702 of the imaging sensor 710. The distance from the optical axis A—A' to each beam splitting means 704 is indicated by "a", whereas the distance from each beam splitting means 704 to the principal point 702 (along the optical axis A—A') is indicated by "b."

[0058] As illustrated, each of the beam splitting means 704 emits a plurality of projection beams 706 that extend radially outward in multiple directions from the beam splitting means 704. Collectively, each set of projection beams 706 forms a projection line 708. In the example illustrated in FIG. 7A, the projection line 708 of each set of projection beams 706 resembles at least a portion of a ring.

[0059] FIG. 7B illustrates a more three-dimensional view of the projection pattern that may be emitted by the distance sensor 700 of FIG. 7A. As illustrated, each group of projection beams 706_1-706_o (hereinafter collectively referred to as "projection beams 706") emitted by a given beam splitting means 704 collectively forms a beam plane 714_1-714_m (hereinafter collectively referred to as "beam planes 714"). In one embodiment, the projection beams 706 forming a given beam plane 714 are projected in a vertical direction against the beam plane 714. The various beam planes 714 created by different groups of projection beams 706 may overlap as shown. In addition, the visual appearance of each beam plane 714 may vary based on the projection pattern emitted by the associated beam splitting means 704. For instance, the beam plane 714_1 may appear visually different from the beam plane 714_m based on different patterns of points of light created by the respective groups of projection beams.

[0060] FIG. 7C illustrates another view of the distance sensor 700 of FIG. 7A in which the concept of tilt angle is visible. As illustrated, the projection direction of the example beam plane 714_m formed by a group of projection beams including the projection beam 706_o forms a tilt angle, α, between the beam plane 714_m and an axis extending radially from the imaging sensor's principal point. In the illustrated example, tilting the beam planes by the tilt angle α can minimize the overlap of multiple beam planes. Tilting the beam planes can also make it easier to distinguish between individual points of light projected onto a surface, which allows for the distance from the distance sensor 700 to an object to be calculated using a relatively simple algorithm.

[0061] FIGs. 8A and 8B, for instance, illustrate the concepts from which a simple algorithm for calculating the distance to an object using the sensor of FIGs. 7A-7C can be derived. Referring to FIG. 8A, the height z, depth y, and length x of the vector r_0 from O_p to D can be computed as follows:

$$z = r_0 \sin\theta \qquad \text{(EQN. 4)}$$

$$y = r_0 \cos\theta \sin\alpha \qquad \text{(EQN. 5)}$$

$$x = r_0 \cos\theta \cos\alpha \qquad \text{(EQN. 6)}$$

Thus,

$$r_0^2 = x^2 + y^2 + z^2 \qquad \text{(EQN. 7)}$$

[0062] Referring to FIG. 8B, when the height is decreased by b and the length is increased by a, the dimensions can be computed as:

$$z - b = R_0 \sin\varphi \qquad \text{(EQN. 8)}$$

$$y = R_0 \cos\varphi \sin\beta \qquad \text{(EQN. 9)}$$

$$x + a = R_0 \cos\varphi \cos\beta \qquad \text{(EQN. 10)}$$

Thus,

$$R_0^2 = (x + a)^2 + y^2 + (z - b)^2 \qquad \text{(EQN. 11)}$$

[0063] From EQN. 4 and EQN 8, one can derive:

$$R0 \sin\varphi + b = r0 \sin\theta \qquad \text{(EQN. 12)}$$

[0064] From EQN. 5 and EQN 9, one can derive:

$$R_0 \cos\varphi \sin\beta = r_0 \cos\theta \sin\alpha \qquad \text{(EQN. 13)}$$

[0065] From EQN. 6 and EQN 10, one can derive:

$$R_0 \cos\varphi \cos\beta - a = r_0 \cos\theta \cos\alpha \qquad \text{(EQN. 14)}$$

[0066] Thus,

$$R_0 = \frac{\alpha \sin\beta + b \cos\theta \cos\alpha}{\cos\varphi \cos\beta \sin\theta - \sin\varphi \cos\theta \cos\alpha} \qquad \text{(EQN. 15)}$$

[0067] β and φ are measured from an image captured by the imaging sensor; a, b, and α are known from the imaging sensor/projection settings; and θ is known from the projection pattern.

[0068] FIG. 9 illustrates the concepts of FIGs. 8A-8B extended to an example distance sensor 900. The example distance sensor 900 includes a light source 902 (including a beam splitting means), a ring-shaped array 904 of second beam splitting means, and an imaging sensor 906 (including a wide-angle lens). The example distance sensor 900 is configured to project a pattern of light that forms a virtual sphere 908.

[0069] FIGs. 10A and 10B illustrate another embodiment of a distance sensor 1000 of the present disclosure. In particular, FIG. 10A illustrates a simplified exploded view of the distance sensor 1000, while FIG. 10B illustrates a simplified cross-sectional view of the distance sensor 1000 of FIG. 10A.

[0070] In particular FIGs. 10A and 10B illustrate only a subset of the components used to produce the projection beams and omit, for example, the imaging sensor and housing. Thus, the distance sensor 1000 generally comprises at least one light source (e.g., a laser light source) 1004, a first beam splitting means 1006, and a second beam splitting means 1008. In one embodiment, the second beam splitting means 1008 comprises a single ring-shaped device, such as a holographic film or other material, having multiple projection points that are capable of splitting individual beams of light into groups of beams. In addition, the distance sensor 1000 includes a conical mirror 1002.

[0071] In this case, the first beam splitting means 1006 splits a primary beam emitted by the light source 1004 into a plurality of secondary beams. Each of the secondary beams is then incident upon a surface of the conical mirror 1002, which redirects each of the secondary beams towards the second beam splitting means 1008. Each projection point on the second beam splitting means 1008 splits a secondary beam into a plurality of tertiary or projection beams as described above.

[0072] FIGs. 11A and 11B illustrate another embodiment of a distance sensor 1100 of the present disclosure. In particular, FIG. 11A illustrates a simplified exploded view of the distance sensor 1100, while FIG. 11B illustrates a simplified cross-sectional view of the distance sensor 1100 of FIG. 11A.

[0073] In particular FIGs. 11A and 11B illustrate only a subset of the components used to produce the projection beams and omit, for example, the imaging sensor and housing. Thus, similar to the distance sensor 1000 illustrated in FIGs. 10A and 10B, the distance sensor 1100 generally comprises at least one light source (e.g., a laser light source) 1104, a first beam splitting means 1106, and an array of second beam splitting means 1108_1-1108_n (and hereinafter collectively referred to as “second beam splitting means 1108”). In this case, multiple individual second beam splitting means 1008 are arranged in a ring-shaped array. The array is positioned around the periphery of a pyramidal or multi-faceted mirror 1102.

[0074] In this case, the first beam splitting means 1106 splits a primary beam emitted by the light source 1104 into a plurality of secondary beams. Each of the secondary beams is then incident upon a surface of the pyramidal mirror 1102, which redirects each of the secondary beams towards one of the second beam splitting means 1108. Each one of the second beam splitting means 1108 splits a secondary beam into a plurality of tertiary or projection beams as described above.

[0075] While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. An apparatus, comprising:

an image capturing device positioned to capture an image of a field of view; and

a first plurality of projection points arranged around a first lens of the image capturing device, wherein each projection point of the first plurality of projection points is configured to emit a plurality of projection beams in different directions within the field of view.

2. The apparatus of claim 1, wherein the plurality of first projection points is positioned behind a principal point of the image capturing device, relative to a direction in which each plurality of projection beams propagates.

3. The apparatus of claim 1, further comprising:

a light source configured to emit a single beam of light; and

a beam splitting means positioned to split the single beam of light into a plurality of beams and to direct each beam of the plurality of beams toward one projection point of the first plurality of projection points.

4. The apparatus of claim 3, further comprising:

a conical mirror positioned between the beam splitting means and the first plurality of projection points.

5. The apparatus of claim 3, further comprising:

a multi-faceted mirror positioned between the beam splitting means and the first plurality of projection points.

6. The apparatus of claim 3, wherein the beam splitting means comprises a holographic film.

7. The apparatus of claim 3, wherein the light source is a laser light source.

8. The apparatus of claim 3, wherein the light source is a pulsed light source.

9. The apparatus of claim 3, wherein the light source includes circuitry to adjust an intensity of the single beam of light.

10. The apparatus of claim 1, further comprising:

a plurality of light sources, wherein each of the plurality of light sources is configured to emit a beam of light and to direct the beam of light toward one projection point of the first plurality of projection points.

11. The apparatus of claim 10, wherein each projection point of the first plurality of projection points comprises a beam splitting means configured to split a beam of light into the plurality of projection beams.

12. The apparatus of claim 10, wherein the beam splitting means comprises a holographic film.

13. The apparatus of claim 12, wherein the beam splitting means comprises a plurality of individual beam splitting means arranged in a ring-shaped array.

14. The apparatus of claim 12, wherein the beam splitting means comprises a single ring-shaped device around which the plurality of projection points is arramged.

15. The apparatus of claim 1, wherein each projection point of the first plurality of projection points is configured to project a different visual pattern using a respective plurality of projection beams.

16. The apparatus of claim 1, wherein the first plurality of projection points is arranged to create a spherical pattern with the plurality of projection beams.

17. The apparatus of claim 1, wherein the first plurality of projection points is arranged to create a ring-shaped pattern with the plurality of projection beams.

18. The apparatus of claim 1, wherein the first plurality of projection points is arranged to create a pattern of parallel lines or planes with the plurality of projection beams.

19. The apparatus of claim 1, wherein the first plurality of projection points is arranged to create a triangular pattern with the plurality of projection beams.

20. The apparatus of claim 1, wherein the first lens is a wide-angle lens that renders a hemispherical shape to the field of view.

21. The apparatus of claim 1, further comprising:

a second lens of the image capturing device, wherein the second lens is points in a direction that is 180 degrees from a direction in which the first lens points; and

a second plurality of projection points arranged around the second lens, wherein each projection point of the second plurality of projection points is configured to emit a plurality of projection beams in different directions within the field of view.

22. The apparatus of claim 1, further comprising:

circuitry to compute a distance between the apparatus and an object positioned in the field of view, using an image captured by the image capturing device.

23. A method for calculating a distance to an object, the method comprising:

projecting a plurality of projection beams from each of a plurality of projection points, wherein the plurality of projection points is arranged around a lens of an image capturing device, and wherein each beam of the plurality of projection beams is directed in a different direction within a field of view;

capturing an image of the field of view, wherein the object is visible in the image and a projection patterns generated by the plurality of projection beams is also visible in the image; and

calculating the distance to the object using information in the image.

24. The method of claim 23, further comprising:

emitting a single beam of light using a light source, wherein the plurality of projection points is positioned between the light source and the lens;

splitting the single beam of light into a plurality of beams by a beam splitting means positioned between the light source and the plurality of projection points; and

directing each beam of the plurality of beams toward one projection point of the plurality of projection points by the beam splitting means.

25. The method of claim 23, further comprising:

emitting a plurality of beams of light by a plurality of light sources, wherein each beam of light of the plurality of beams of light is directed toward one projection point of the plurality of projection points.

26. The method of claim 23, wherein the field of view is hemispherical in shape.

27. A computer-readable storage device storing a plurality of instructions which, when executed by a processor, cause the processor to perform operations for calculating a distance to an object, the operations comprising:

projecting a plurality of projection beams from each of a plurality of projection points, wherein the plurality of projection points is arranged around a lens of an image capturing device, and wherein each beam of the plurality of projection beams is directed in a different direction within a field of view;

capturing an image of the field of view, wherein the object is visible in the image and a projection patterns generated by the plurality of projection beams is also visible in the image; and

calculating the distance to the object using information in the image.

28. A method for calculating a distance to an object, the method comprising:

projecting a plurality of points of light onto a field of view, from a plurality of projection points;

capturing an image of the field of view, wherein the object is visible in the image and a projection pattern formed by the plurality of points of light is also visible in the image; and

calculating the distance to the object in accordance with a positional relationship between at least two of the plurality of points of light, wherein the at least two of the plurality of points of light are emitted by at least two different projection points of the plurality of projection points.

29. The method of claim 28, wherein the positional relationship is known a priori.

30. A computer-readable storage device storing a plurality of instructions which, when executed by a processor, cause the processor to perform operations for calculating a distance to an object, the operations comprising:

projecting a plurality of points of light onto a field of view, from a plurality of projection points;

capturing an image of the field of view, wherein the object is visible in the image and a projection pattern formed by the plurality of points of light is also visible in the image; and

calculating the distance to the object in accordance with a positional relationship between at least two of the plurality of points of light, wherein the at least two of the plurality of points of light are emitted by at least two different projection points of the plurality of projection points.

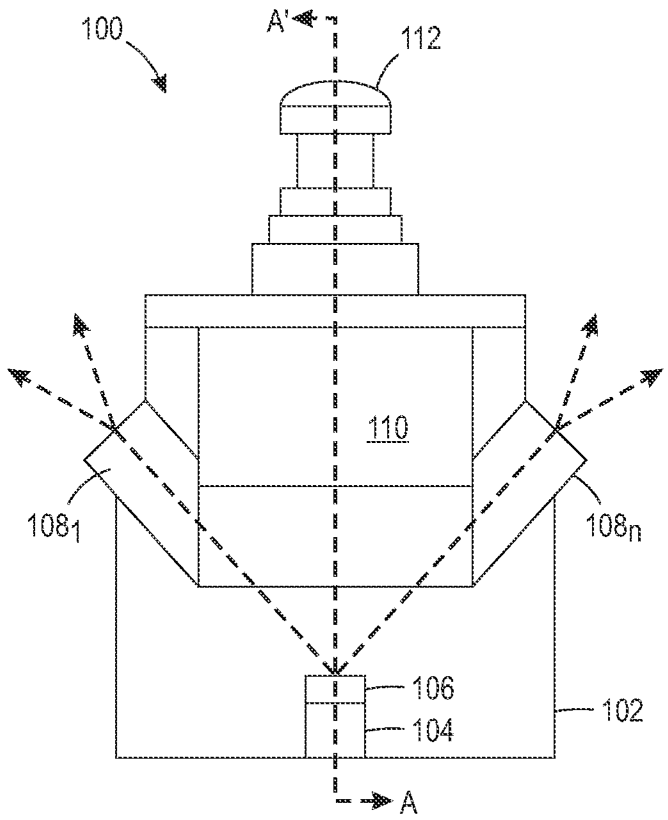

100
A'
112
110
108_1
108_n
106
104
102
A

FIG. 1A

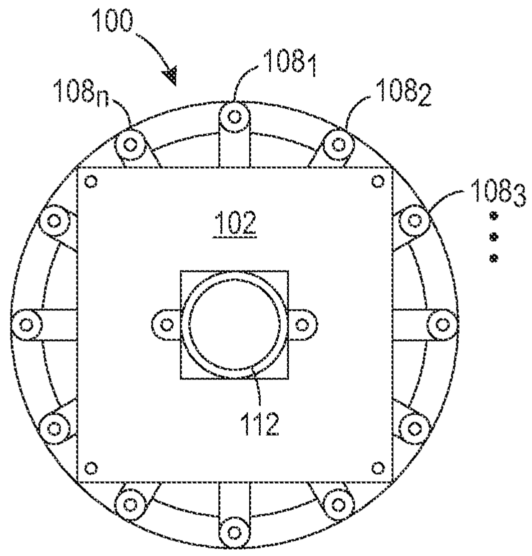

100
108_1
108_n
108_2
108_3
102
112

FIG. 1B

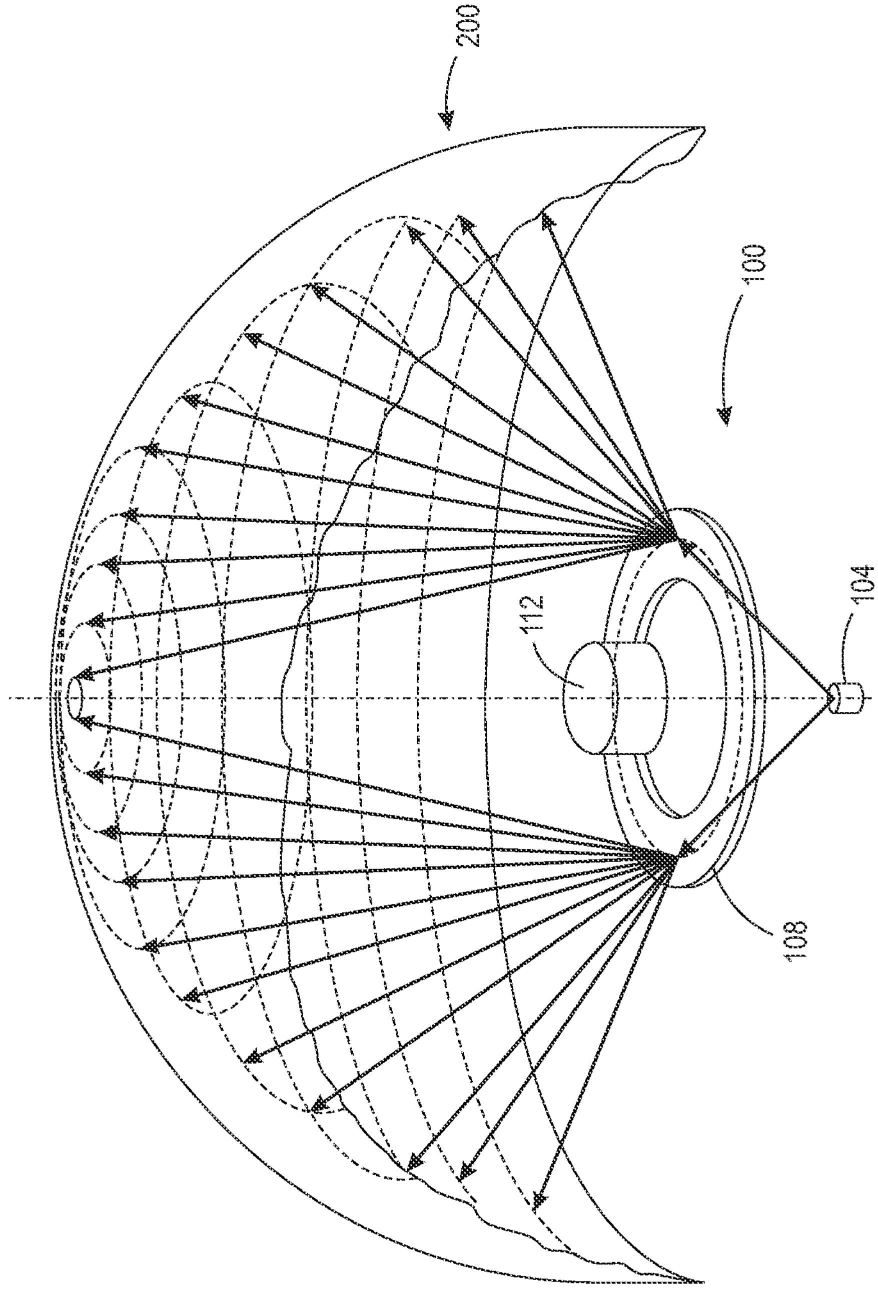
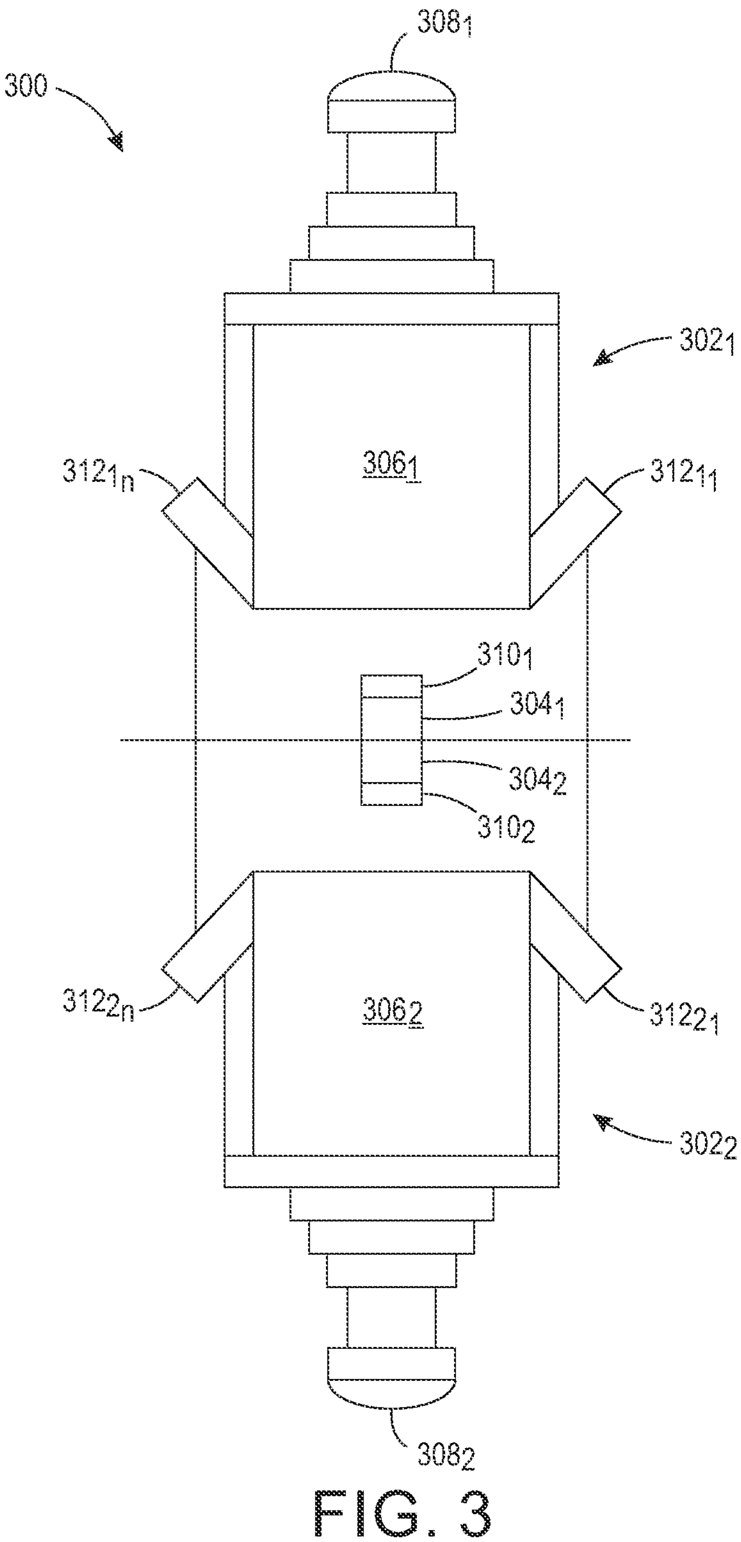


FIG. 2



308_1
300
302_1
306_1
3121_n
3121_1
310_1
304_1
304_2
310_2
3122_n
306_2
3122_1
302_2
308_2

FIG. 3

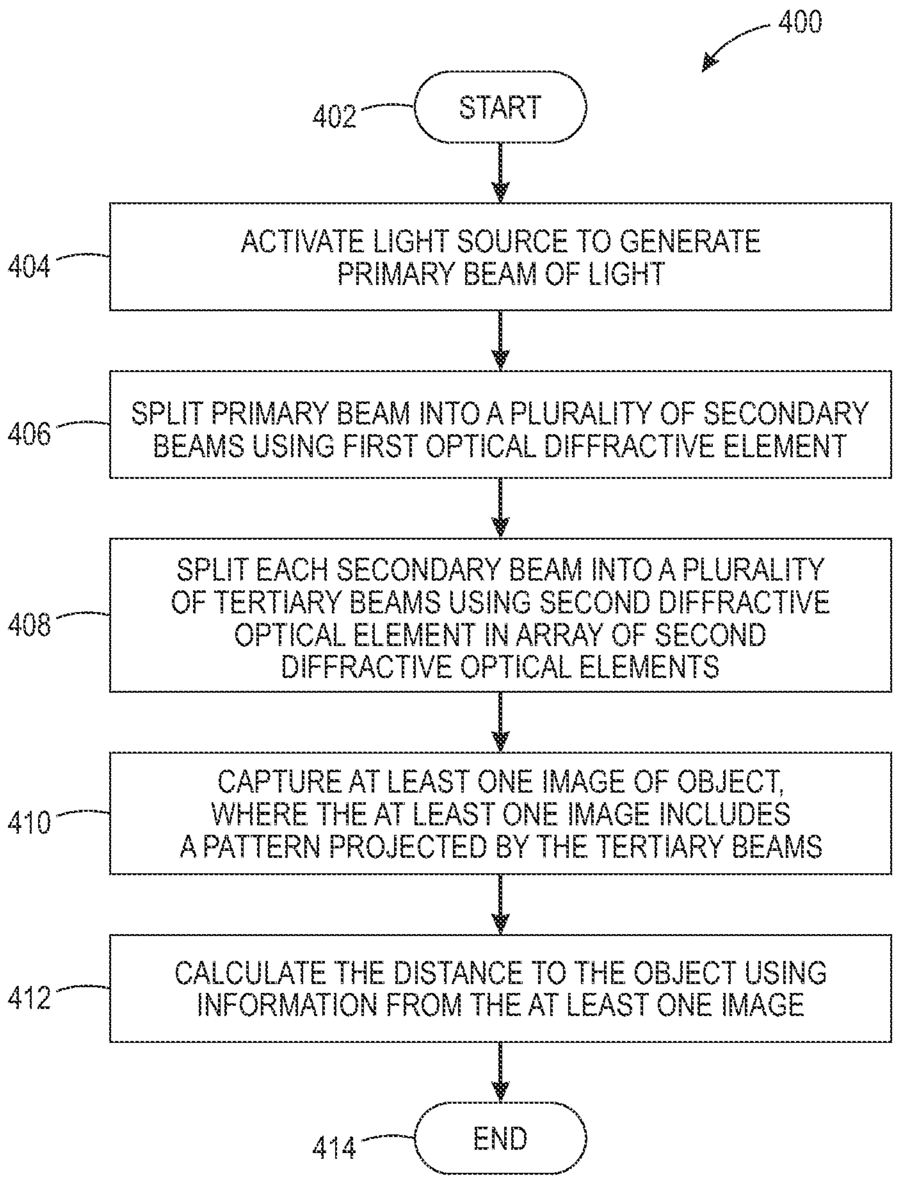

400
402
START
404
ACTIVATE LIGHT SOURCE TO GENERATE PRIMARY BEAM OF LIGHT
406
SPLIT PRIMARY BEAM INTO A PLURALITY OF SECONDARY BEAMS USING FIRST OPTICAL DIFFRACTIVE ELEMENT
408
SPLIT EACH SECONDARY BEAM INTO A PLURALITY OF TERTIARY BEAMS USING SECOND DIFFRACTIVE OPTICAL ELEMENT IN ARRAY OF SECOND DIFFRACTIVE OPTICAL ELEMENTS
410
CAPTURE AT LEAST ONE IMAGE OF OBJECT, WHERE THE AT LEAST ONE IMAGE INCLUDES A PATTERN PROJECTED BY THE TERTIARY BEAMS
412
CALCULATE THE DISTANCE TO THE OBJECT USING INFORMATION FROM THE AT LEAST ONE IMAGE
414
END

FIG. 4

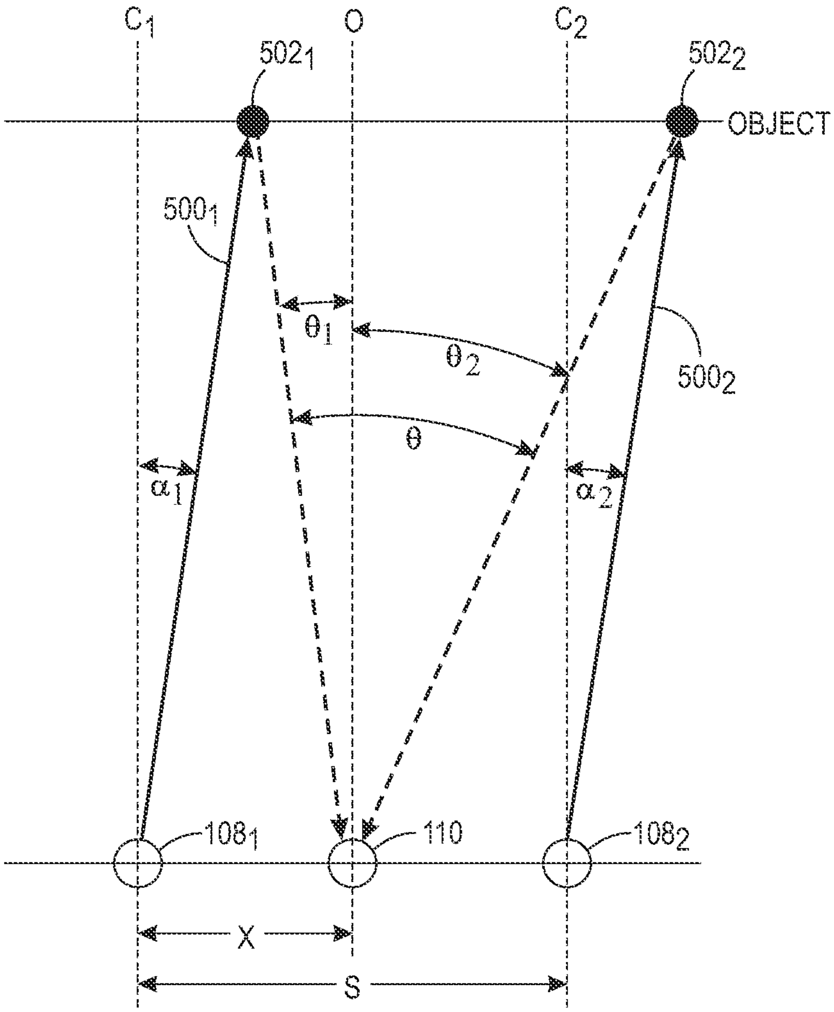


FIG. 5

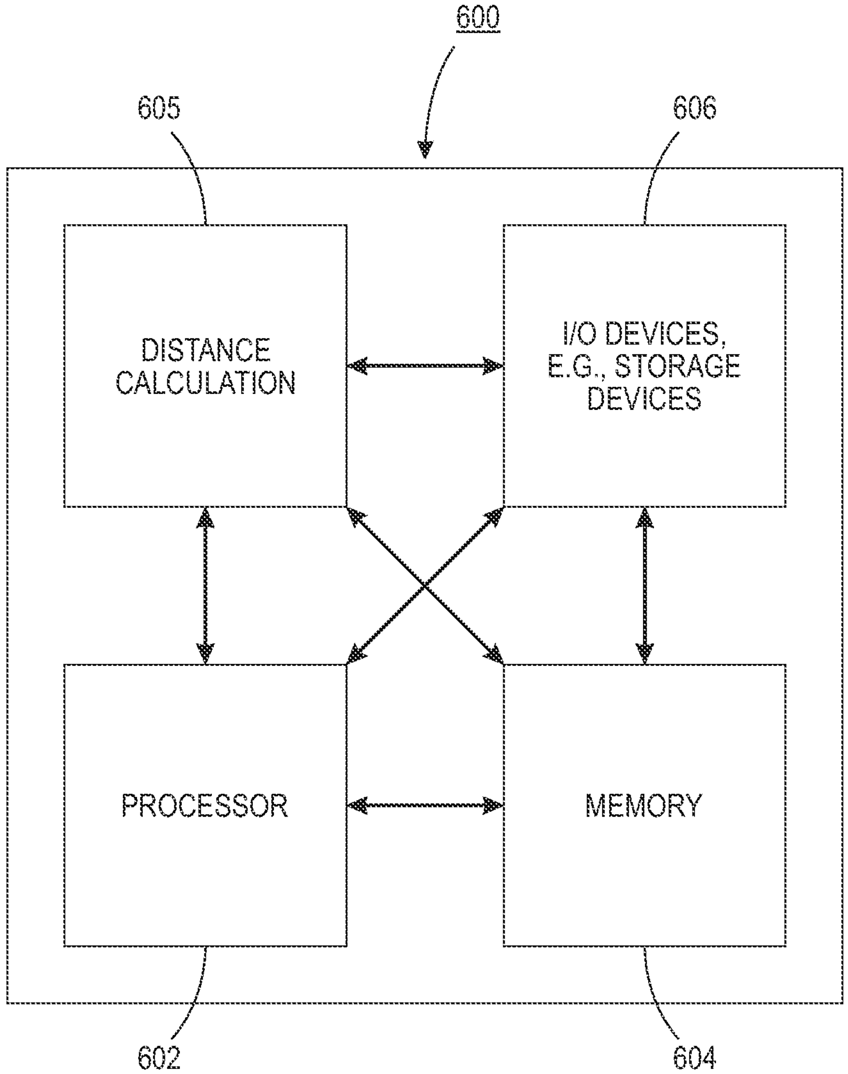

600
605
606
DISTANCE CALCULATION
I/O DEVICES, E.G., STORAGE DEVICES
PROCESSOR
MEMORY
602
604

FIG. 6

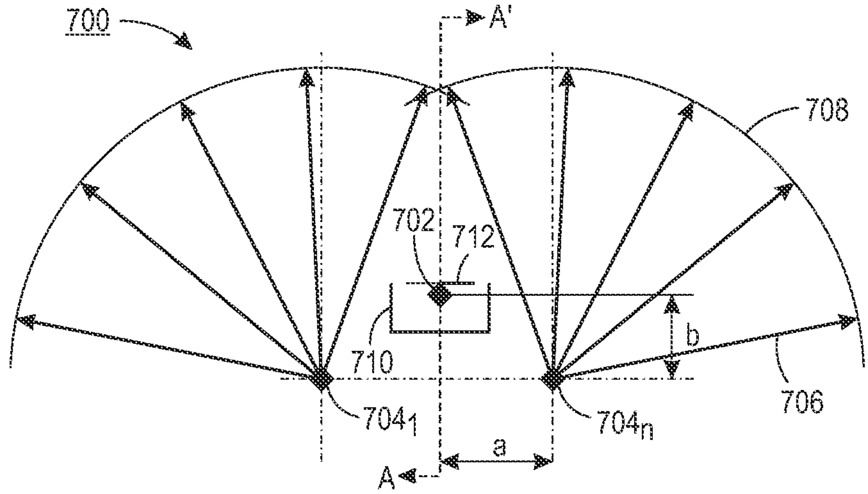

700
A'
708
702
712
b
710
706
704_1
704_n
a
A

FIG. 7A

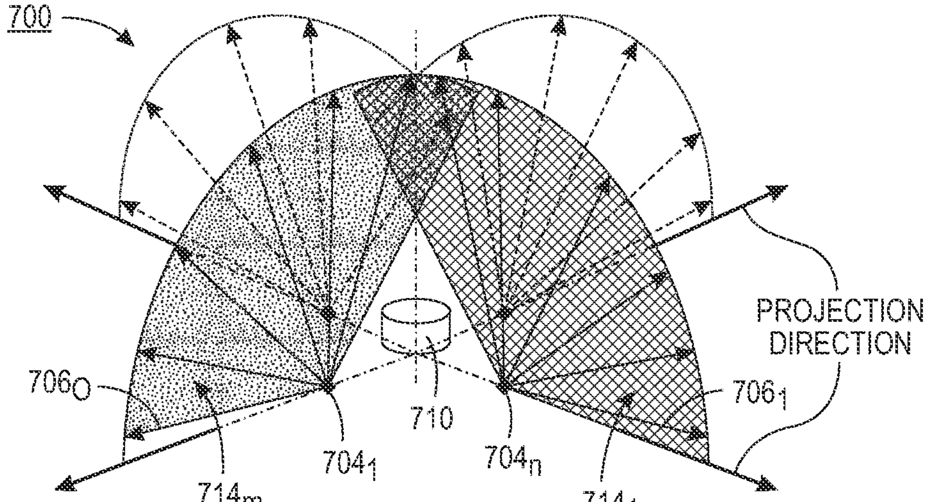

700
PROJECTION DIRECTION
706_O
706_1
710
704_1
704_n
714_m
714_1

FIG. 7B

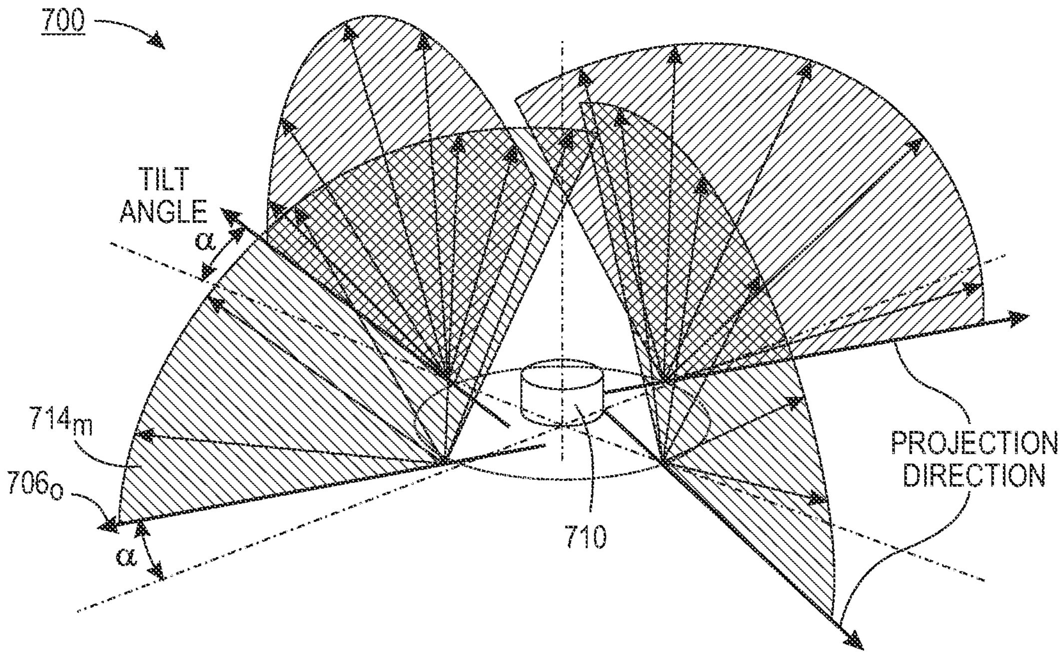


FIG. 7C

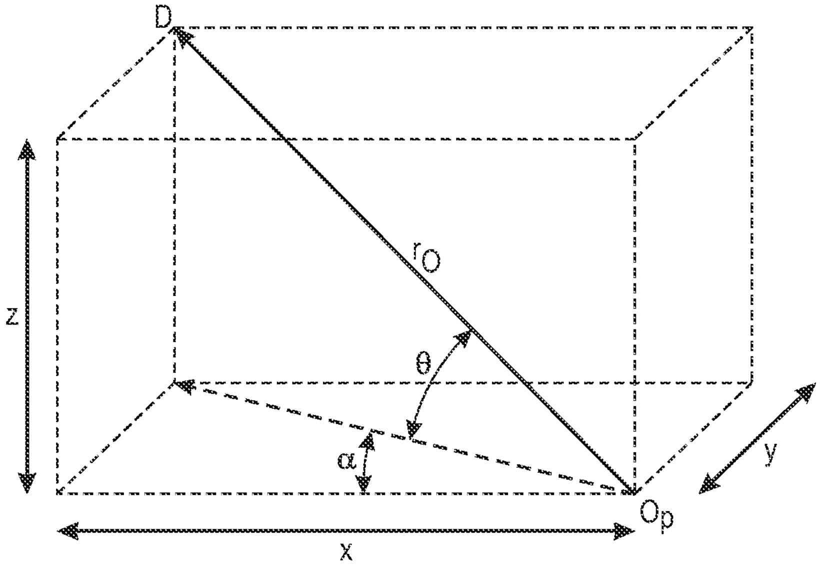


FIG. 8A

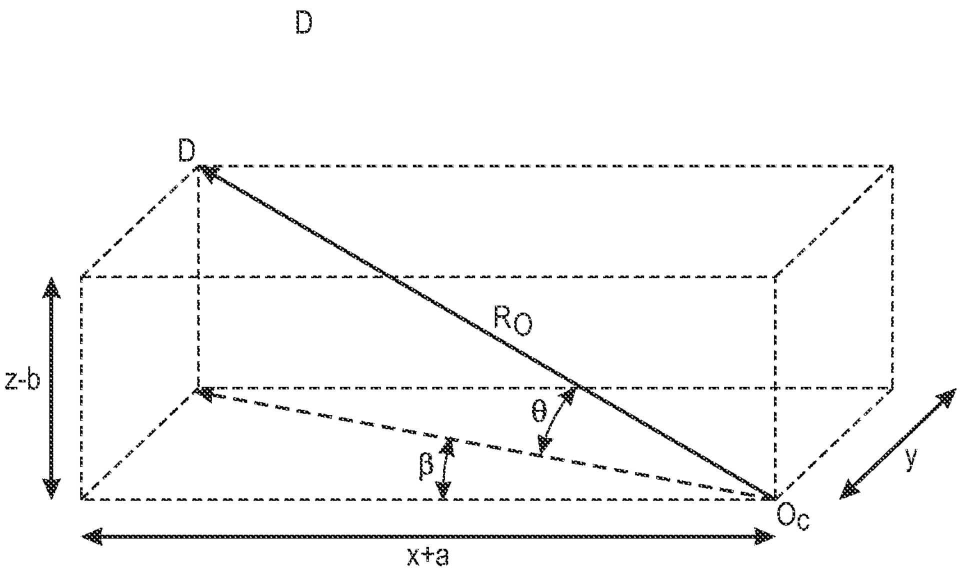


FIG. 8B

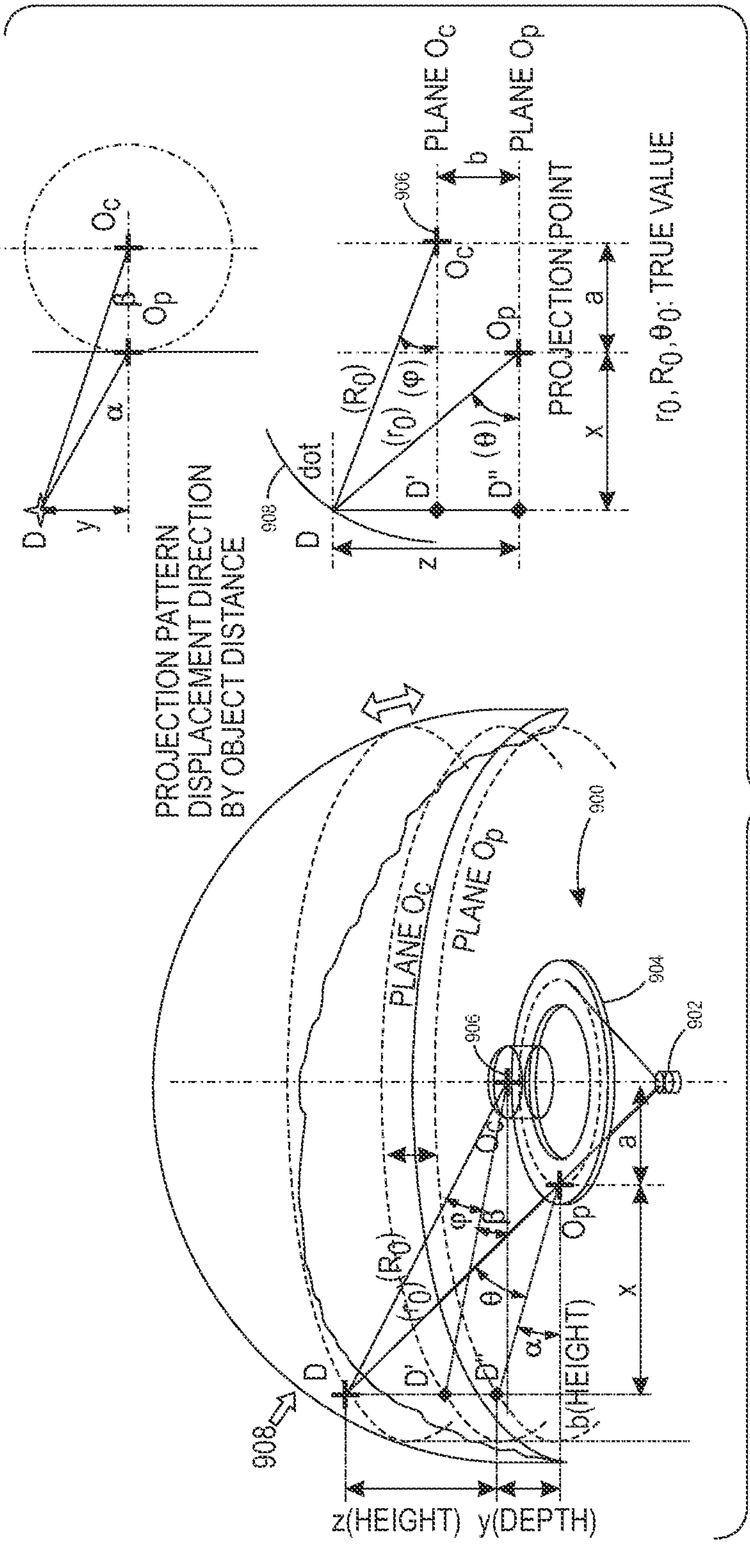

PROJECTION PATTERN
DISPLACEMENT DIRECTION
BY OBJECT DISTANCE
PLANE Oc
PLANE Op
PROJECTION POINT
r0, R0, θ0: TRUE VALUE
dot
z(HEIGHT)
y(DEPTH)
b(HEIGHT)
x(HEIGHT)
908
906
904
902
900

FIG. 9

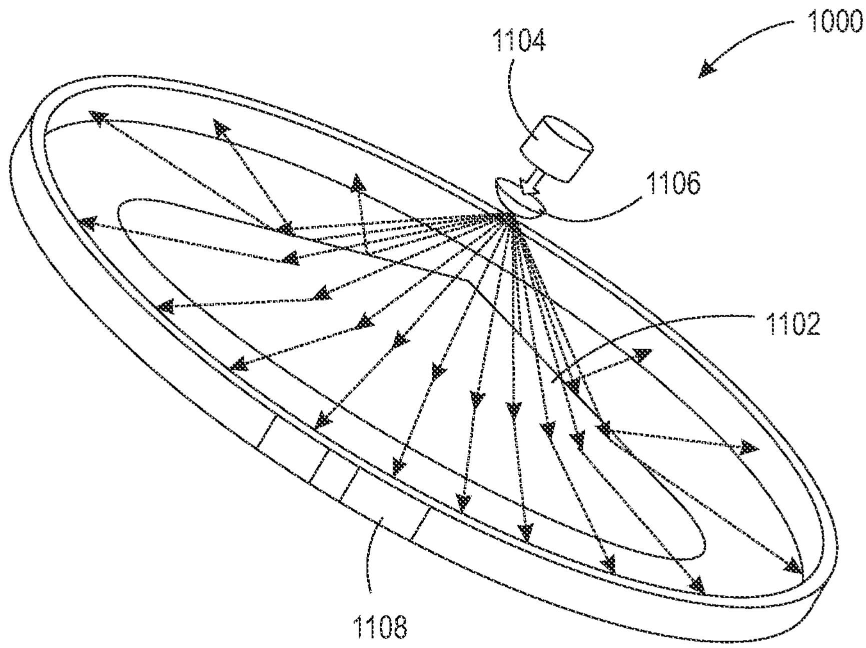


FIG. 10A

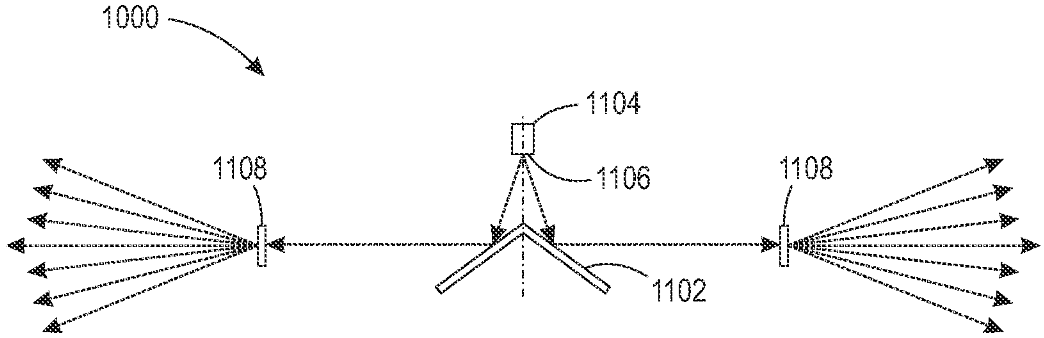


FIG. 10B

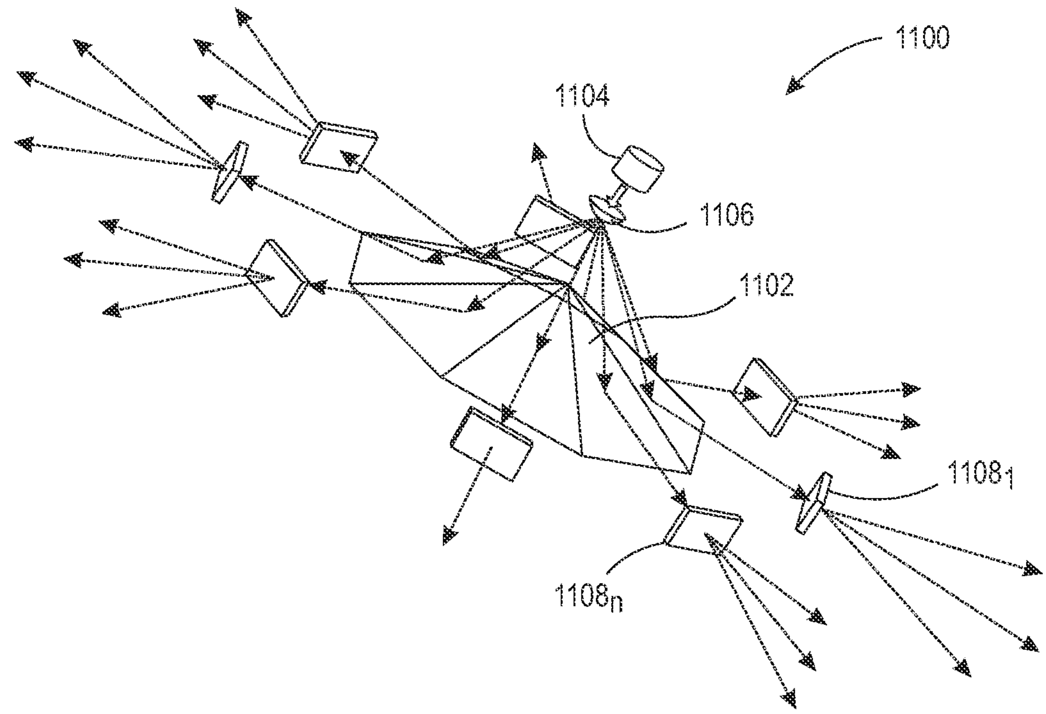


FIG. 11A

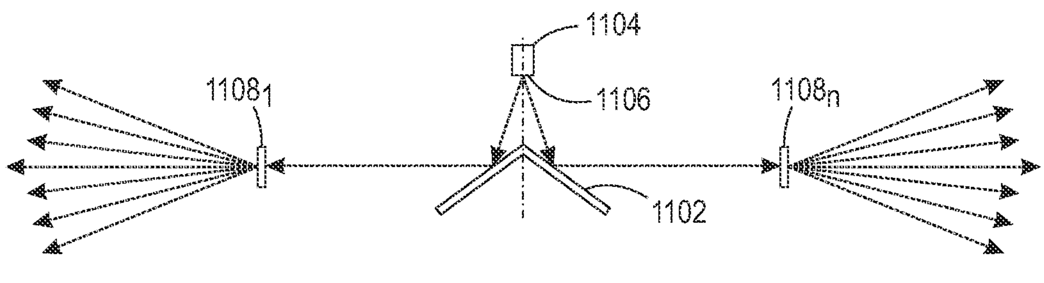


FIG. 11B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/056883

A. CLASSIFICATION OF SUBJECT MATTER

B60R 1/08(2006.01)i, B60R 21/0134(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B60R 1/08; H04N 5/232; H04N 7/18; G05D 1/02; H04N 5/228; H04N 7/00; G01C 3/08; B60R 21/0134

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: image, capture, projection, point, lens, beam, emit and direction

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2007-0206099 A1 (MATSUO et al.) 06 September 2007 See paragraphs [0003], [0005], [0021], [0028], [0070], [0086], [0091], [0101] and figures 1, 7, 9, 12-14, 16.	1-3,6-19,22-25,27-30 4-5,20-21,26
Y	US 2014-0009571 A1 (GENG, ZHENG JASON) 09 January 2014 See paragraphs [0034]-[0035] and figure 3.	4-5,20,26
Y	US 2003-0071891 A1 (GENG, Z. JASON) 17 April 2003 See paragraph [0043] and figure 5.	21
A	WO 2014-131064 A2 (QUNOMIC VIRTUAL TECHNOLOGY, LLC et al.) 28 August 2014 See pages 5-6 and figures 1-3.	1-30
A	US 2012-0113252 A1 (YANG et al.) 10 May 2012 See paragraphs [0024], [0034]-[0035] and figures 1, 7-8.	1-30

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 January 2016 (12.01.2016)	**13 January 2016 (13.01.2016)**

Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea	LEE, Hun Gil
Facsimile No. +82-42-472-7140	Telephone No. +82-42-481-8525

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		CN 101030252 A	05/09/2007
		EP 1830306 A2	05/09/2007
		EP 1830306 A3	12/09/2007
		EP 1830306 B1	10/03/2010
		JP 2007-233231 A	13/09/2007
		JP 4799216 B2	26/10/2011
		KR 10-0919041 B1	24/09/2009
		US 7777808 B2	17/08/2010
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		US 8471892 B2	25/06/2013
		WO 2008-066742 A1	05/06/2008
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		WO 2014-131064 A3	16/10/2014
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		TW I428558 B	01/03/2014

(19)中华人民共和国国家知识产权局

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2017.06.23
(86)PCT国际申请的申请数据
PCT/US2015/056883 2015.10.22
(87)PCT国际申请的公布数据
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代理人 周学斌 杜荔南
(51)Int.Cl.
G01B 11/02(2006.01)
G06K 9/00(2006.01)

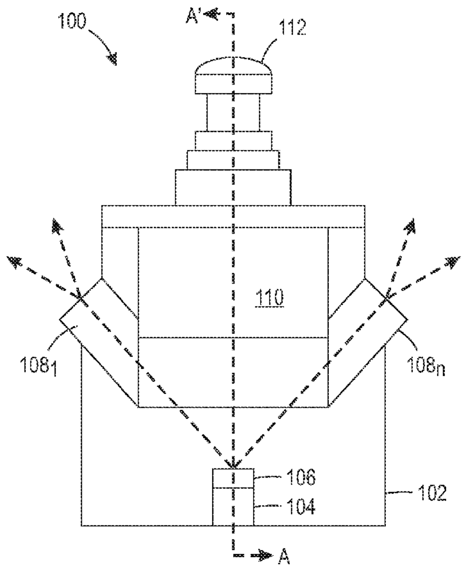
权利要求书3页 说明书9页 附图11页

(54)发明名称

距离传感器

(57)摘要

在一个实施例中，一种距离传感器包括：被定位成捕获视场中的图像的图像捕获装置以及被布置在该图像捕获装置的第一透镜周围的第一多个投影点，其中该第一多个投影点中的每个投影点都被配置成在视场内的不同方向上发射多个投影射束。



CN 107407553 A

1.一种设备,包括:

图像捕获装置,其被定位成捕获视场中的图像;以及

第一多个投影点,其被布置在该图像捕获装置的第一透镜周围,其中该第一多个投影点中的每个投影点都被配置成在视场内的不同方向上发射多个投影射束。

2.根据权利要求1所述的设备,其中相对于该多个投影射束中的每一个传播的方向,该多个第一投影点被定位在图像捕获装置的主点后面。

3.根据权利要求1所述的设备,进一步包括:

光源,其被配置成发射单个光射束;以及

射束分离装置,其被定位成将该单个光射束分离成多个射束并且指引多个射束中的每个射束朝向第一多个投影点的一个投影点。

4.根据权利要求3所述的设备,进一步包括:

圆锥形反射镜,其被定位在该射束分离装置和第一多个投影点之间。

5.根据权利要求3所述的设备,进一步包括:

多面反射镜,其被定位在该射束分离装置和第一多个投影点之间。

6.根据权利要求3所述的设备,其中该射束分离装置包括全息胶片。

7.根据权利要求3所述的设备,其中该光源是激光器光源。

8.根据权利要求3所述的设备,其中该光源是脉冲光源。

9.根据权利要求3所述的设备,其中该光源包括用来调整单个光射束的强度的电路。

10.根据权利要求1所述的设备,进一步包括:

多个光源,其中该多个光源中的每一个被配置成发射光射束并且指引该光射束朝向该第一多个投影点中的一个投影点。

11.根据权利要求10所述的设备,其中该第一多个投影点中的每个投影点都包括被配置成将光射束分离成多个投影射束的射束分离装置。

12.根据权利要求10所述的设备,其中该射束分离装置包括全息胶片。

13.根据权利要求12所述的设备,其中该射束分离装置包括以环形阵列布置的多个单独的射束分离装置。

14.根据权利要求12所述的设备,其中该射束分离装置包括单个环形装置,在该单个环形装置周围布置多个投影点。

15.根据权利要求1所述的设备,其中该第一多个投影点中的每个投影点都被配置成使用各自的多个投影射束来投射不同视觉图样。

16.根据权利要求1所述的设备,其中该第一多个投影点被布置成利用多个投影射束来创建球形图样。

17.根据权利要求1所述的设备,其中该第一多个投影点被布置成利用多个投影射束来创建环形图样。

18.根据权利要求1所述的设备,其中该第一多个投影点被布置成利用多个投影射束来创建平行线或平行面的图样。

19.根据权利要求1所述的设备,其中该第一多个投影点被布置成利用多个投影射束来创建三角形图样。

20.根据权利要求1所述的设备,其中该第一透镜是向视场呈现半球形状的广角透镜。

21.根据权利要求1所述的设备,进一步包括:

图像捕获装置的第二透镜,其中该第二透镜指向与第一透镜所指向的方向成180度的方向;以及

第二多个投影点,其被布置在该第二透镜周围,其中该第二多个投影点中的每个投影点都被配置成在视场内的不同方向上发射多个投影射束。

22.根据权利要求1所述的设备,进一步包括:

使用由图像捕获装置捕获的图像来计算该设备和定位在视场中的对象之间的距离的电路。

23.一种用于计算到对象的距离的方法,该方法包括:

从多个投影点中的每一个投射多个投影射束,其中该多个投影点被布置在图像捕获装置的透镜周围,并且其中在视场内的不同方向上指引该多个投影射束中的每个射束;

捕获视场的图像,其中该对象在图像中可见并且由多个投影射束生成的投影图样也在图像中可见;以及

使用该图像中的信息来计算到对象的距离。

24.根据权利要求23所述的方法,进一步包括:

使用光源发射单个光射束,其中该多个投影点被定位在光源和透镜之间;

通过定位于光源和多个投影点之间的射束分离装置将单个光射束分离成多个射束;以及

通过射束分离装置指引多个射束中的每个射束朝向多个投影点中的一个投影点。

25.根据权利要求23所述的方法,进一步包括:

用多个光源发射多个光射束,其中指引该多个光射束中的每个光射束朝向多个投影点中的一个投影点。

26.根据权利要求23所述的方法,其中该视场是半球形形状的。

27.一种计算机可读存储设备,其存储当被处理器执行时促使该处理器实行用于计算到对象的距离的操作的多个指令,该操作包括:

从多个投影点中的每一个投射多个投影射束,其中该多个投影点被布置在图像捕获装置的透镜周围,并且其中在视场内的不同方向上指引该多个投影射束中的每个射束;

捕获视场的图像,其中该对象在图像中可见并且由多个投影射束生成的投影图样也在图像中可见;以及

使用该图像中的信息来计算到对象的距离。

28.一种用于计算到对象的距离的方法,该方法包括:

从多个投影点将多个光点投射到视场上;

捕获视场的图像,其中该对象在图像中可见并且由多个光点形成的投影图样也在图像中可见;以及

根据该多个光点中的至少两个之间的位置关系来计算到对象的距离,其中由多个投影点中的至少两个不同投影点来发射该多个光点中的至少两个。

29.根据权利要求28所述的方法,其中该位置关系是先验已知的。

30.一种计算机可读存储设备,其存储当被处理器执行时促使该处理器实行用于计算到对象的距离的操作的多个指令,该操作包括:

从多个投影点将多个光点投射到视场上；

捕获视场的图像，其中该对象在图像中可见并且由多个光点形成的投影图样也在图像中可见；以及

根据该多个光点中的至少两个之间的位置关系来计算到对象的距离，其中由多个投影点中的至少两个不同投影点来发射该多个光点中的至少两个。

距离传感器

[0001] 相关申请的交叉引用

本申请要求保护2014年10月24日提交的美国临时专利申请序列号62/068,250以及2015年5月10日提交的美国临时专利申请序列号62/159,286的权益。通过引用将这两个申请以它们的整体并入本文。

技术领域

[0002] 本公开总体上涉及计算机视觉系统,并且更特别地涉及用于测量交通工具和空间中的对象或点之间的距离的传感器。

背景技术

[0003] 诸如机器人交通工具和无人机之类的无人驾驶交通工具通常依赖于用于周围环境中的障碍物检测和导航的计算机视觉系统。这些计算机视觉系统进而通常依赖于从周围环境获取视觉数据的各种传感器,计算机视觉系统处理该数据以便收集关于周围环境的信息。例如,经由一个或多个成像传感器获取的数据可被用来确定从交通工具到周围环境中的特定对象或点的距离。

发明内容

[0004] 在一个实施例中,一种距离传感器包括:图像捕获装置,其被定位成捕获视场中的图像;以及第一多个投影点,其被布置在该图像捕获装置的第一透镜周围,其中该第一多个投影点中的每个投影点都被配置成在视场内的不同方向上发射多个投影射束。

[0005] 在另一实施例中,一种用于计算到对象的距离的方法包括:从多个投影点中的每一个投射多个投影射束,其中该多个投影点被布置在图像捕获装置的透镜周围,并且其中在视场内的不同方向上指引该多个投影射束中的每个射束;捕获视场的图像,其中该对象在图像中可见并且由多个投影射束生成的投影图样也在图像中可见;以及使用该图像中的信息来计算到对象的距离。

[0006] 在另一实施例中,一种计算机可读存储设备,其存储当被处理器执行时促使该处理器实行用于计算到对象的距离的操作的多个指令。该操作包括:从多个投影点中的每一个投射多个投影射束,其中该多个投影点被布置在图像捕获装置的透镜周围,并且其中在视场内的不同方向上指引该多个投影射束中的每个射束;捕获视场的图像,其中该对象在图像中可见并且由多个投影射束生成的投影图样也在图像中可见;以及使用该图像中的信息来计算到对象的距离。

[0007] 在另一实施例中,一种用于计算到对象的距离的方法包括:从多个投影点将多个光点投射到视场上;捕获视场的图像,其中该对象在图像中可见并且由多个光点形成的投影图样也在图像中可见;以及根据该多个光点中的至少两个之间的位置关系来计算到对象的距离,其中由多个投影点中的至少两个不同投影点来发射该多个光点中的至少两个。

[0008] 在另一实施例中,一种计算机可读存储设备存储当被服务器的处理器执行时促使

该处理器实行用于计算到对象的距离的操作的多个指令。该操作包括：从多个投影点将多个光点投射到视场上；捕获视场的图像，其中该对象在图像中可见并且由多个光点形成的投影图样也在图像中可见；以及根据该多个光点中的至少两个之间的位置关系来计算到对象的距离，其中由多个投影点中的至少两个不同投影点来发射该多个光点中的至少两个。

附图说明

[0009] 可以通过结合附图来考虑下面的详细描述来容易地理解本公开的教导，在附图中：

图1A图示本公开的距离传感器的一个实施例的横截面视图；

图1B图示图1A的距离传感器的俯视图；

图2图示图1A和1B的距离传感器的示例视场；

图3图示具有近似360度视场的距离传感器的一个实施例；

图4图示用于计算从传感器到空间中的对象或点的距离的方法的流程图；

图5图示可通过其来计算从传感器到对象或点的距离的三角测量技术；

图6描绘适合于在执行本文中描述的功能中使用的通用计算机的高级框图；

图7A图示被配置成投射环形图样的距离传感器的一个简化示例；

图7B图示可由图7A的距离传感器发射的投影图样的更三维化的视图；

图7C图示在其中倾斜角的概念可见的图7A的距离传感器的另一视图；

图8A和8B图示可以从其导出用于使用图7A-7C的传感器来计算到对象的距离的简单算法的概念；

图9图示扩展至示例距离传感器的图8A-8B的概念；

图10A和10B图示本公开的距离传感器的另一实施例；以及

图11A和11B图示本公开的距离传感器的另一实施例。

[0010] 为了促进理解，在可能的情况下已经使用相同的参考数字来标出各图中共同的相同元件。

具体实施方式

[0011] 在一个实施例中，本公开涉及一种距离传感器。可在无人驾驶交通工具中使用距离传感器，以便帮助计算机视觉系统确定从该交通工具到周围环境中的特定对象或点的距离。例如，距离传感器可将一个或多个光射束投射到该对象或点上并且然后根据飞行时间(TOF)、对反射的光的分析(例如激光雷达)或其他装置来计算距离。然而，这种类型的常规距离传感器往往体积大，并且因此可能不适合于在紧凑交通工具中使用。此外，该传感器可能制造起来是非常昂贵的并往往具有有限的视场。例如，即使使用多个常规成像传感器的布置也提供小于360度的视场。

[0012] 本公开的实施例提供一种制造上经济的紧凑距离传感器，其包括很少移动部件或没有移动部件，并且可以在高达360度的视场中测量距离。在一个实施例中，该传感器使用一组射束分离装置(诸如衍射光学元件(DOE)阵列)来在广角透镜周围生成多个投影点。该多个投影点中的每一个都将多个射束发射到视场中。从射束的外观来说，传感器可以在180度半球视场中测量距离。通过背靠背地安装两个此类传感器，可以在360度视场中测量距

离。DOE使得有可能将由单个光源(例如激光器)生成的射束分离成被投射在视场中的对象或点上的多个投影射束。然而,在其他实施例中,通过DOE来使由多个光源发射的射束分离。然后可以在投影和来自多个投影的图像捕获的一个循环中计算从传感器到该对象或点的距离。

[0013]　图1A和1B图示本公开的距离传感器100的一个实施例。特别地,图1A图示距离传感器100的横截面视图,而图1B图示图1A的距离传感器100的俯视图。距离传感器100可被安装到例如无人机交通工具。

[0014]　如图1A中所图示的,该距离传感器100包括布置在紧凑外壳102内的多个部件。该部件包括至少一个光源104,第一射束分离装置(在下文中被称为第一衍射光学元件106)、第二射束分离装置阵列(在下文中被称为第二衍射光学元件1081-108n(并且在下文中被统称为"第二衍射光学元件108"))、以及包括广角透镜112的成像传感器110。

[0015]　基本上围绕中心轴A-A'对称地布置该部件。在一个实施例中,中心轴A-A'与成像传感器110的光轴相一致。在一个实施例中,该光源104被定位在中心轴A-A'的第一端部处。在一个实施例中,该光源104是沿着中心轴A-A'发射单个光射束的激光器光源。在下文中,由光源104发射的单个射束也可被称为"主射束"。在一个实施例中,该光源104发射已知对人类视觉来说相对安全的波长的光(例如红外线)。在另一实施例中,该光源104可以包括用来调整其输出的强度的电路。在另一实施例中,该光源104可以脉冲形式发射光,以便减轻环境光对图像捕获的影响。

[0016]　该第一衍射光学元件(DOE)106被定位成沿着中心轴A-A'接近光源104(例如相对于由光源104发射的光所传播的方向,在光源104的"前面")。特别地,该第一DOE 106被定位成拦截由光源104发射的单个光射束并且将单个射束或主射束分离成多个二次射束。在一个实施例中,中心轴A-A'和二次射束中的每一个之间的角度是相等的。该第一DOE 106是能够将主射束分离成多个二次射束(其在不同方向上从该主射束偏离)的任何光学部件。例如,在一个实施例中,该第一DOE 106可包括圆锥形反射镜或全息胶片。在这种情况下,以圆锥形状来布置在该多个二次射束。在另一些实施例中,可通过装置而不是衍射来使该主射束分离。

[0017]　第二DOE 108的阵列被定位成沿着中心轴A-A'接近第一DOE 106(例如相对于由光源104发射的光所传播的方向,在第一DOE 106的"前面")。特别地,该第二DOE 108的阵列被定位成使得第一DOE 106被定位在光源104和第二DOE 108的阵列之间。如在图1B中更清楚图示的,在一个实施例中,以环形阵列来布置第二DOE 108,其中中心轴A-A'通过环的中心并且在该环周围以规则间隔将该第二DOE 108隔开。例如,在一个实施例中,在该环周围以近似三十度将该第二DOE 108隔开。在一个实施例中,相对于由光源104发射的光所传播的方向,第二DOE 108的阵列被定位在成像传感器110的主点"后面"(即光轴A—A'与图像面相交处的点)。

[0018]　每个第二DOE 108都被定位成拦截由第一DOE 106产生的二次射束之一并且将该二次射束分离成以径向方式远离第二DOE 108指引的多个(例如两个或更多个)三次射束。因此,每个第二DOE 108都限定从其将一组投影射束(或三次射束)发射到视场中的传感器100的投影点。在一个实施例中,多个三次射束中的每一个相应地成扇形散开以覆盖近似一百度的范围。第二DOE 108是能够将相应的二次射束分离成多个三次射束(其在不同方向上

从该二次射束偏离)的任何光学部件。例如,在一个实施例中,每一个第二DOE可包括圆锥形反射镜或全息胶片。然而,在其他实施例中,通过装置而不是衍射来使该二次射束分离。

[0019] 在一个实施例中,以扇形或径向图样来布置每多个三次射束,在各射束中的每一个之间具有相等的角度。在一个实施例中,各第二DOE 108中的每一个都被配置成投射在表面上创建不同视觉图样的三次射束。例如,一个第二DOE 108可投射圆点图样,而另一第二DOE 108可以投射线或x图样。

[0020] 成像传感器110被定位成沿着中心轴A'A',在第二DOE 108的阵列的中间(例如相对于由光源104发射的光所传播的方向,至少部分在第二DOE 108的阵列的“前面”)。在一个实施例中,该成像传感器110是图像捕获装置,诸如静止或视频相机。如上文所讨论的,该成像传感器110包括创建半球视场的广角透镜,诸如鱼眼透镜。在一个实施例中,该成像传感器110包括用于计算从距离传感器110到对象或点的距离的电路。在另一实施例中,该成像传感器包括用于通过网络将所捕获的图像传达给处理器的网络接口,在这里处理器计算从距离传感器100到对象或点的距离并且然后将所计算的距离传达返回给距离传感器100。

[0021] 因此,在一个实施例中,该距离传感器100使用单个光源(例如光源104)来产生从其来发射各组投影射束(例如包括圆点图样或线图样)的多个投影点。可以从视场中投影射束的外观来计算从距离传感器100到对象的距离(如下面更详细讨论的)。特别地,第一和第二DOE的使用使得有可能从由光源发射的单个光射束在透镜周围生成多个投影点。这允许距离传感器100当在宽视场内测量距离的同时保持相对紧凑的形状因子。该成像传感器110和光源104还可以被安装在同一面中以便使设计更紧凑;然而,在一个实施例中,第二DOE 108_1-108_n被定位在成像传感器110的主点后面以便增加可以被投影射束覆盖的视场(例如以使得该视场的深度角更靠近全180度,或者在某些情况下甚至更大)。

[0022] 此外,因为第二DOE 108中的每一个都投射不同图样的三次射束,所以成像传感器中的电路可以容易地确定所捕获的图像中的哪些射束是由第二DOE 108中的哪些创建的。如在下面更详细讨论的,这便利于距离计算。

[0023] 尽管传感器100被图示为包括仅单个光源104(这降低了传感器100中部件的总数),但是在备选实施例中,传感器可包括多个光源。在这种情况下,第一DOE 106可能不是必须的。反而,在一个实施例中,多个光源中的每个光源可对应于DOE阵列(诸如图1A和图1B中的第二DOE 108的阵列)中的一个DOE。值得注意地,该配置仍产生在成像传感器的透镜周围并且可从发射各组投影射束的多个投影点(例如由阵列中的每个DOE来限定一个投影点)。

[0024] 图2图示图1A和1B的距离传感器100的示例视场200。在图2中,还以分解视图图示距离传感器100的某些部件。如所示,视场200基本上是半球形形状。此外,由距离传感器100产生的多个三次光射束将光图样投射在“虚拟”半球上。该图样由所图示的一系列同心圆来表示,在这里每个三次射束都会遇到半球。该圆被描绘为随着离距离传感器100的距离的增加而在尺寸上逐渐减小,以便示出由三次射束创建的图样如何在视觉上由于对象距离而改变。

[0025] 如图2中所示,距离传感器100的视场覆盖近似180度。在一个实施例中,可以通过背靠背地安装两个距离传感器将该视场扩展到近似360度。

[0026] 图3例如图示具有近似360度的视场的距离传感器300的一个实施例。该距离传感

器300实际上包括两个距离传感器302_1和302_2，它们被配置成类似于图1A和1B的距离传感器100但是以背靠背的布置来安装，即以使得两个距离传感器302_1和302_2的各自光源304_1和304_2邻近，但是在相反的方向上投射它们的主射束(即在两个主射束之间存在180度的差)。

[0027] 如所图示的，两个距离传感器302_1和302_2可被配置成基本上类似于图1A和1B的距离传感器100。因此，每个距离传感器302_1和302_2包括各自的光源304_1和304_2、各自的成像传感器306_1和306_2、各自的广角透镜308_1和308_2、各自的第一DOE 310_1和310_2、以及第二DOE 312_{11}-312_{1n}和312_{21}-312_{2n}的各自的圆形阵列。然而，成像传感器306_1或306_2可共享用于计算从距离传感器300到对象或点的距离的电路或网络接口。

[0028] 值得注意地，在该实施例中，第二DOE 312_{11}-312_{1n}和312_{21}-312_{2n}被定位在它们的各自成像传感器306_1和306_2的主点的后面。成像传感器306_1和306_2(以及尤其透镜308_1和308_2)和第二DOE 312_{11}-312_{1n}和312_{21}-312_{2n}的该相对定位允许由距离传感器300投射的射束图样覆盖更大的视场(例如更接近对于每个距离传感器302_1和302_2的全180度，或者更接近对于作为一个整体的传感器300的全360度)。

[0029] 图4图示用于计算从传感器到空间中的对象或点的距离的方法400的流程图。在一个实施例中，可由集成在成像传感器中的处理器(诸如图1A中图示的成像传感器110)或者如在图5中图示并且在下文所讨论的通用计算设备来执行该方法400。

[0030] 方法400在步骤402中开始。在步骤404中，激活光源以生成光的主射束。在一个实施例中，由单个光源来生成单个主射束；然而，在其他实施例中，由多个光源来生成多个主射束。在一个实施例中，一个光源或多个光源包括激光器光源。

[0031] 在可选步骤406中，使用定位在该主射束沿着其传播的路径中的第一射束分离装置(例如衍射光学元件)来将该主射束分离成多个二次射束。该第一射束分离装置可以是例如圆锥反射镜。例如，当距离传感器(成像传感器是其一部分)包括仅单个光源时执行步骤406。

[0032] 在步骤408中，使用射束分离装置阵列中的第二射束分离装置(例如第二衍射光学元件)将多个二次射束中的每个射束分离成多个投影或三次射束。在一个实施例中，以环形来定位多个第二射束分离装置，以使得每个第二射束分离装置都被定位在二次射束之一沿其传播的路径中。在一个实施例中，第二射束分离装置中的至少一些是圆锥反射镜。在其中距离传感器包括多个光源的一个实施例中，该方法400可直接从步骤404进行到步骤408。在这种情况下，(使用多个光源生成的)该多个主射束中的每一个主射束都被第二射束分离装置之一直接分离成多个投影射束。

[0033] 在步骤410中，捕获该对象或点的至少一个图像。该图像包括被投射到该对象或点上以及周围空间上的图样。通过将一系列圆点、线或其他形状投射到该对象、点或周围空间上的各投影射束中的每一个来创建图样。

[0034] 在步骤412中，使用来自在步骤410中捕获的图像的信息来计算从传感器到该对象或点的距离。在一个实施例中，使用三角测量技术来计算该距离。例如，由传感器投射的各图样的各部分之间的位置关系可以被用作用于计算的基础。

[0035] 该方法400在步骤414中结束。因此，结合在图1A-1B中或图3中描绘的传感器的方法400可以在图像捕获和计算的单个循环中测量从传感器到空间中的对象或点的距离。

[0036] 图5例如图示三角测量技术，在步骤412中可通过该三角测量技术计算从传感器到

对象或点的距离。特别地，图5图示图1的示例成像传感器110以及可用两个第二衍射光学元件108_1和108_2限定的两个投影点。该各投影点与成像传感器110隔开相等的距离x，以使得在两个投影点之间存在距离s(例如x = s/2)。各投影点中的每一个发射相应的投影射束500_1和500_2，其被入射在对象上以创建图样中的相应点502_1和502_2(例如圆点或线)。通过成像传感器110来检测这些点502_1和502_2并且它们可被用来如下计算成像传感器110和对象之间的距离D：

$$D = s/(-\tan\alpha_2 + \tan\alpha_1 + \tan\theta_2 + \tan\theta_1) \qquad \text{(等式1)}$$

在这里α_2是在第二衍射光学元件108_2的中心轴c_2和投影射束500_2之间形成的角，α_1是在第二衍射光学元件108_1的中心轴c_1和投影射束500_1之间形成的角，θ_2是在成像传感器110的中心光轴O和成像传感器110以其来感知由投影射束500_2创建的点502_2的角之间形成的角，并且θ_1是在成像传感器110的中心光轴O和成像传感器110以其来感知由投影射束500_1创建的点502_1的角之间形成的角。

[0037]　从下面的关系式来导出等式1：

$$D*\tan\alpha_1 + D*\tan\theta_1 = x \qquad \text{(等式2)}$$

$$D*\tan\alpha_2 + D*\tan\theta_2 = s-x \qquad \text{(等式3)}$$

等式2和3允许计算从投影图样(包括例如圆点图样)的源到将投影图样投射到其上的对象的距离。当用不同投影点在该源周围发射各光点时，基于形成投影图样的各光点(例如圆点)之间的位置关系来计算该距离。在该实施例中，各光点之间的位置关系是先验已知的(即不被测量而作为计算的一部分)。

[0038]　图6描绘适合于在执行本文所述的功能中使用的通用计算机的高级框图。如在图6中所描绘的，系统600包括一个或多个硬件处理器元件602(例如中央处理单元(CPU)、微处理器、或多核处理器)、存储器604(例如随机存取存储器(RAM)和/或只读存储器(ROM))、用于计算距离的模块605、和各种输入/输出装置606(例如存储装置，包括但不限于磁带驱动器、软盘驱动器、硬盘驱动器或光盘驱动器、接收器、发射器、透镜和光学器件、输出端口、输入端口和用户输入装置(诸如键盘、键区、鼠标、麦克风等等))。尽管示出了仅一个处理器元件，但是应该指出通用计算机可采用多个处理器元件。此外，尽管在图中示出了仅一个通用计算机，但是如果对于特定说明性示例以分布式或并行方式来实施如上文所讨论的(一个或多个)方法(即跨多个通用计算机或并行通用计算机来实施(一个或多个)上述方法或(一个或多个)整个方法的步骤)，则意图使该图的通用计算机代表这些多个通用计算机中的每一个。此外，一个或多个硬件处理器可以被利用来支持虚拟化或共享的计算环境。该虚拟化计算环境可支持代表计算机、服务器或其他计算设备的一个或多个虚拟机。在此类虚拟化虚拟机中，诸如硬件处理器和计算机可读存储装置之类的硬件部件可被虚拟化或在逻辑上表示。

[0039]　应该指出，可以以软件和/或软件和硬件的组合的方式来实施本公开，例如使用专用集成电路(ASIC)、可编程逻辑阵列(PLA)(包括现场可编程门阵列(FPGA)、或部署在硬件设备、通用计算机或任何其他硬件等同物上的状态机，例如关于上文讨论的(一个或多个)方法的计算机可读指令可以被用来配置硬件处理器以执行上文公开的方法的步骤、功能和/或操作。在一个实施例中，针对用于计算距离的本模块或过程605的指令和数据(例如包括计算机可执行指令的软件程序)可以被加载到存储器604中并且由硬件处理器元件602来

执行以实施如上文结合示例方法400讨论的步骤、功能或操作。此外，当硬件处理器执行指令来实行“操作”时，这可以包括直接实行操作和/或促进、指引另一硬件装置或部件(例如协处理器等等)或与之合作以实行操作的硬件处理器。

[0040] 执行与上文描述的(一个或多个)方法有关的计算机可读或软件指令的处理器可以被认为是编程的处理器或专用处理器。照此，用于计算本公开的距离(包括相关联的数据结构)的本模块605可以被存储在有形或物理(概括为非瞬时)计算机可读存储装置或介质(例如易失性存储器、非易失性存储器、ROM存储器、RAM存储器、磁性或光学驱动器、装置或磁盘等等)上。更具体地，该计算机可读存储装置可包括提供存储信息(诸如被处理器或计算装置(诸如计算机或应用程序服务器)访问的数据和/或指令)的能力的任何物理装置。

[0041] 如上文所讨论的，例如如由诸如衍射光学元件(DOE)之类的射束分离装置限定的投影点集合可以被配置成将各种各样的图样投射到视场上。例如，被投射图样的单独的光点的形状可变化(例如该光点可包括圆点、线等等)。此外，单独的光点可共同形成各种各样的图样，除了其他潜在图样之外还包括环形图样、球形图样、平行线或面的图样、或三角形图样。换言之，成组的单独的光点可以形成具有序类型(ordinality)的一条或多条线(例如具有球形或三角形形状的投影图样或平行线或面的图样)。在一个实施例中，单独的光点之间的序类型是相同的或者共享类似的特性(例如对称、旋转一致、局部一致等等)。此外，各组单独的光点可以形成具有序类型的圆点(例如对于具有环形形状的投影图样)。在一个实施例中，单独的光点之间的序类型是相同的或者共享类似的特性(例如圆点形状、间隔关系等等方面的差异)。

[0042] 图7A图示被配置成投射环形图样的距离传感器700的一个简化示例。通过线A—A’和成像传感器710的主点702(即光轴A—A’和图像面相交处的点)来指示该距离传感器700的光轴。在一个实施例中，射束分离装置704_1-704_n的环(在下文中被统称为“射束分离装置704”)被定位在成像传感器710的主点702后面。用“a”来指示从光轴A—A’到每个射束分离装置704的距离，而用“b”来指示从每个射束分离装置704到主点702(沿着光轴A—A’)的距离。

[0043] 如所图示的，各射束分离装置704中的每一个都发射在多个方向上从射束分离装置704径向向外延伸的多个投影射束706。每一组投影射束706共同地形成投影线708。在图7A中所图示的示例中，每一组投影射束706的投影线708类似于环的至少一部分。

[0044] 图7B图示可由图7A的距离传感器700发射的投影图样的更三维化的视图。如所图示的，由给定射束分离装置704发射的每一组投影射束706_1-706_o(在下文中被统称为“投影射束706”)共同形成射束面714_1-714_m(在下文中被统称为“射束面714”)。在一个实施例中，在垂直方向上对着射束面714投射形成给定射束面714的投影射束706。如所示的那样由不同组的投影射束706创建的各个射束面714可重叠。此外，每个射束面714的视觉外观可基于由相关联的射束分离装置704发射的投影图样来变化。例如，基于由相应的各组投影射束创建的光点的不同图样，射束面714_1可在视觉上看上去与射束面714m不同。

[0045] 图7C图示图7A的距离传感器700的另一视图，在其中倾斜角的概念是可见的。如所图示的，由包括投影射束706_0的一组投影射束形成的示例射束面714m的投影方向在射束面714m和从成像传感器的主点径向延伸的轴之间形成倾斜角α。在所图示的示例中，以倾斜角α使射束面倾斜可以最小化多个射束面的重叠。使射束面倾斜还可以使得更容易地区别投

射在表面上的单独的光点，这允许使用相对简单的算法来计算从距离传感器700到对象的距离。

[0046] 例如图8A和8B图示可以从其导出用于使用图7A-7C的传感器来计算到对象的距离的简单算法的概念。参考图8A，可以如下计算从O_p到D的矢量r_0的高度z、深度y和长度x：

$$z = r_0 \sin\theta \quad \text{(等式4)}$$

$$y = r_0 \cos\theta \sin\alpha \quad \text{(等式5)}$$

$$x = r_0 \cos\theta \cos\alpha \quad \text{(等式6)，}$$

由此，

$$r_0^2 = x^2 + y^2 + z^2 \quad \text{(等式7)。}$$

[0047] 参考图8B，当高度减小b且长度增加a时，各尺寸可以被计算为：

$$z - b = R_0 \sin\varphi \quad \text{(等式8)}$$

$$y = R_0 \cos\varphi \sin\beta \quad \text{(等式9)}$$

$$x + a = R_0 \cos\varphi \cos\beta \quad \text{(等式10)，}$$

由此，

$$R_0^2 = (x + a)^2 + y^2 + (z - b)^2 \quad \text{(等式11)。}$$

[0048] 根据等式4和等式8，可以导出：

$$R0 \sin\varphi + b = r0 \sin\theta \quad \text{(等式12)。}$$

[0049] 根据等式5和等式9，可以导出：

$$R_0 \cos\varphi \sin\beta = r_0 \cos\theta \sin\alpha \quad \text{(等式13)。}$$

[0050] 根据等式6和等式10，可以导出：

$$R_0 \cos\varphi \cos\beta - a = r_0 \cos\theta \cos\alpha \quad \text{(等式14)。}$$

[0051] 由此，

$$R_0 = \frac{a \sin\beta + b \cos\theta \cos\alpha}{\cos\varphi \cos\beta \sin\theta - \sin\varphi \cos\theta \cos\alpha} \quad \text{(等式15)。}$$

[0052] β和φ是从由成像传感器捕获的图像测量的；a、b和α是从成像传感器/投影设置已知的；并且θ是从投影图样已知的。

[0053] 图9图示扩展至示例距离传感器900的图8A-8B的概念。该示例距离传感器900包括光源902(包括射束分离装置)、第二射束分离装置的环形阵列904、以及成像传感器906(包括广角透镜)。该示例距离传感器900被配置成投射形成虚拟球908的光的图样。

[0054] 图10A和10B图示本公开的距离传感器1000的另一实施例。特别地，图10A图示距离传感器1000的简化分解视图，而图10B图示图10A的距离传感器1000的简化横截面视图。

[0055] 特别地，图10A和10B仅图示用来产生投影射束的部件的子集并且省略例如成像传感器和外壳。因此，该距离传感器1000通常包括至少一个光源(例如激光器光源)1004、第一射束分离装置1006和第二射束分离装置1008。在一个实施例中，该第二射束分离装置1008包括具有能够将单独的光射束分离成各组射束的多个投影点的单个环形装置，诸如全息胶片或其他材料。此外，该距离传感器100包括圆锥反射镜1002。

[0056] 在这种情况下，该第一射束分离装置1006将由光源1004发射的主射束分离成多个二次射束。然后将该二次射束中的每一个入射在圆锥反射镜1002的表面上，该圆锥反射镜1002重新指引该二次射束中的每一个朝向第二射束分离装置1008。如上文所述，在第二射

束分离装置1008上的每个投影点将二次射束分离成多个三次或投影射束。

[0057] 图11A和11B图示本公开的距离传感器1100的另一实施例。特别地，图11A图示距离传感器1100的简化分解视图，而图11B图示图11A的距离传感器1100的简化横截面视图。

[0058] 特别地，图11A和11B仅图示用来产生投影射束的部件的子集并且省略例如成像传感器和外壳。因此，类似于图10A和10B中图示的距离传感器1000，该距离传感器1100通常包括至少一个光源（例如激光器光源）1104、第一射束分离装置1106和第二射束分离装置1108_1-1108_n的阵列（并且在下文中被统称为“第二射束分离装置1008”）。在这种情况下，以环形阵列来布置多个单独的第二射束分离装置1008。该阵列被定位在锥体或多面反射镜1102的边缘的周围。

[0059] 在这种情况下，该第一射束分离装置1106将由光源1104发射的主射束分离成多个二次射束。然后将该二次射束中的每一个入射在锥体反射镜1102的表面上，其朝向第二射束分离装置1108中的一个重新指引该二次射束中的每一个。如上文所述，各第二射束分离装置1008中的每一个将二次射束分离成多个三次或投影射束。

[0060] 尽管已经在上文描述了各种实施例，但是应该理解已经仅通过示例的方式提出各种实施例，并且不作为限制。因此，不应该通过上述示例性实施例中的任一个来限制优选实施例的广度和范围，而是应该仅根据以下权利要求以及它们的等同物来限定优选实施例的广度和范围。

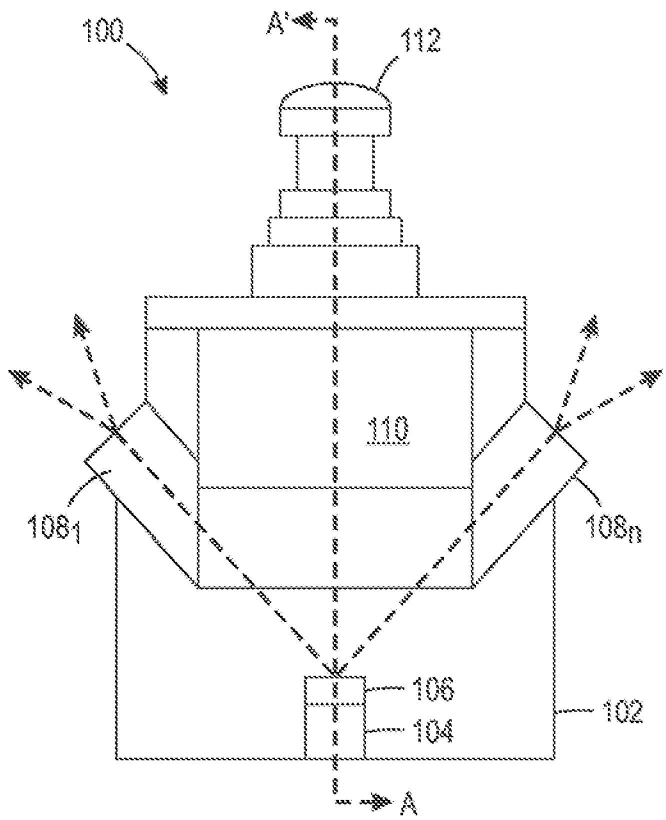

100
A'
112
110
108_1
108_n
106
104
102
A

图 1A

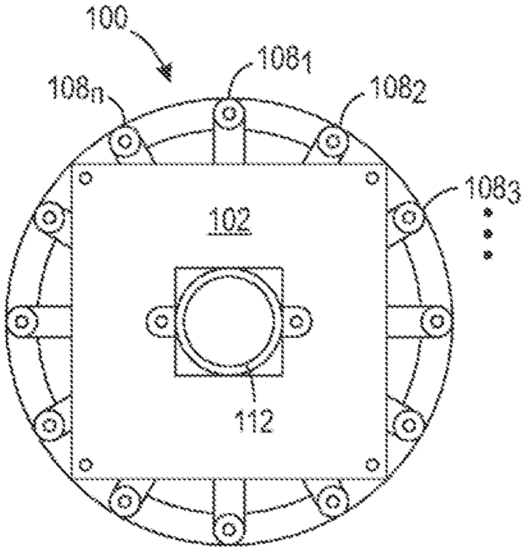

100
108_n
108_1
108_2
108_3
102
112

图 1B

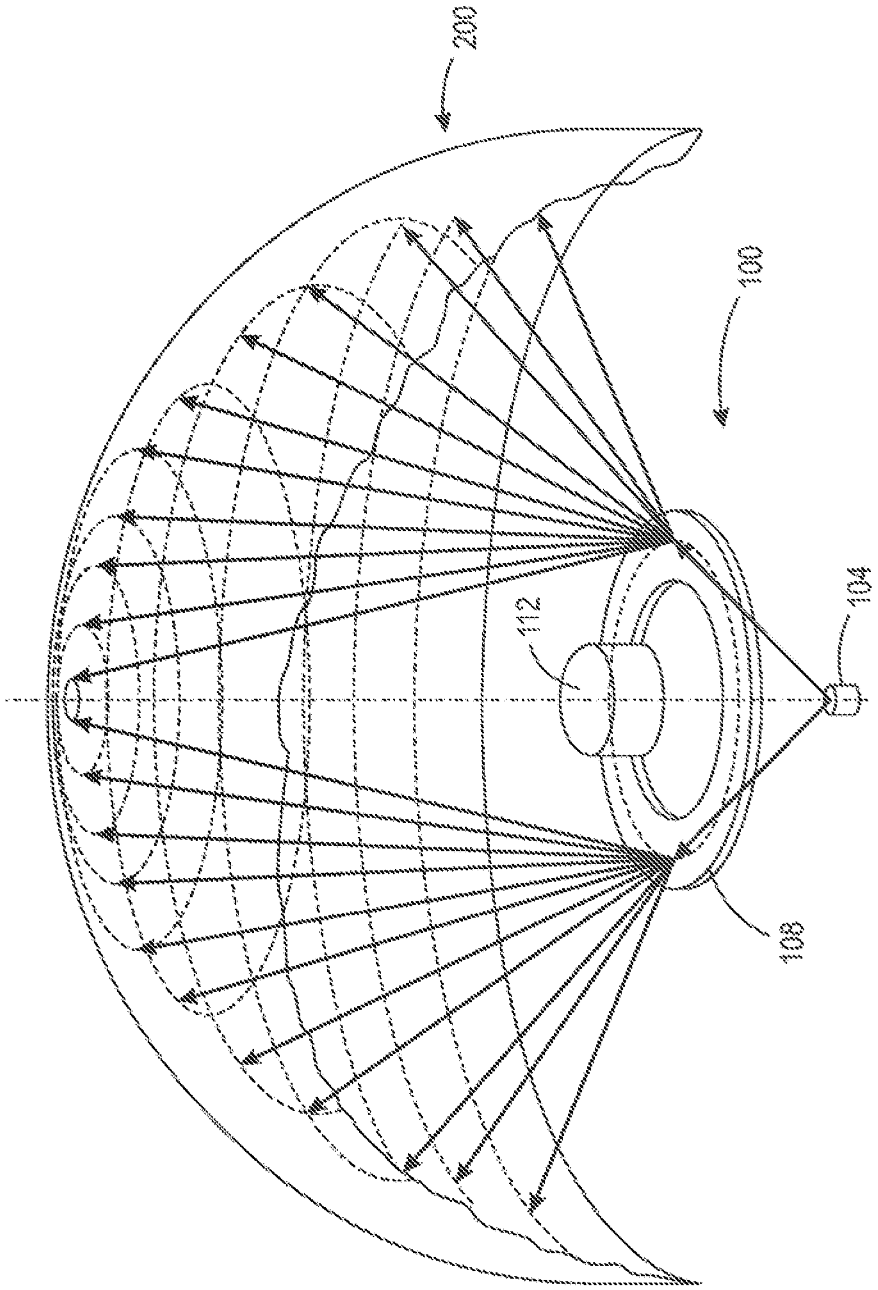
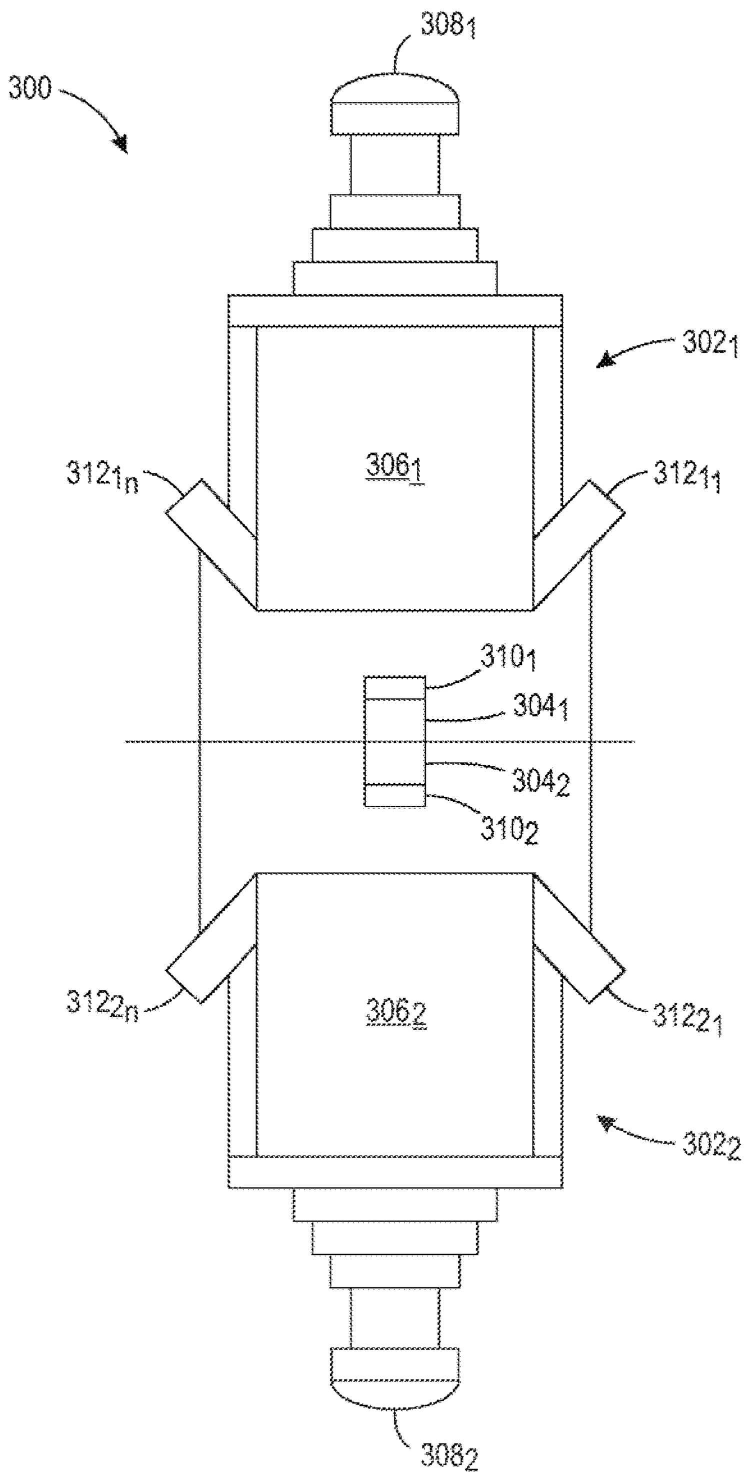


图 2



308_1
300
302_1
312_{1n}
306_1
312_{11}
310_1
304_1
304_2
310_2
312_{2n}
306_2
312_{21}
302_2
308_2

图 3

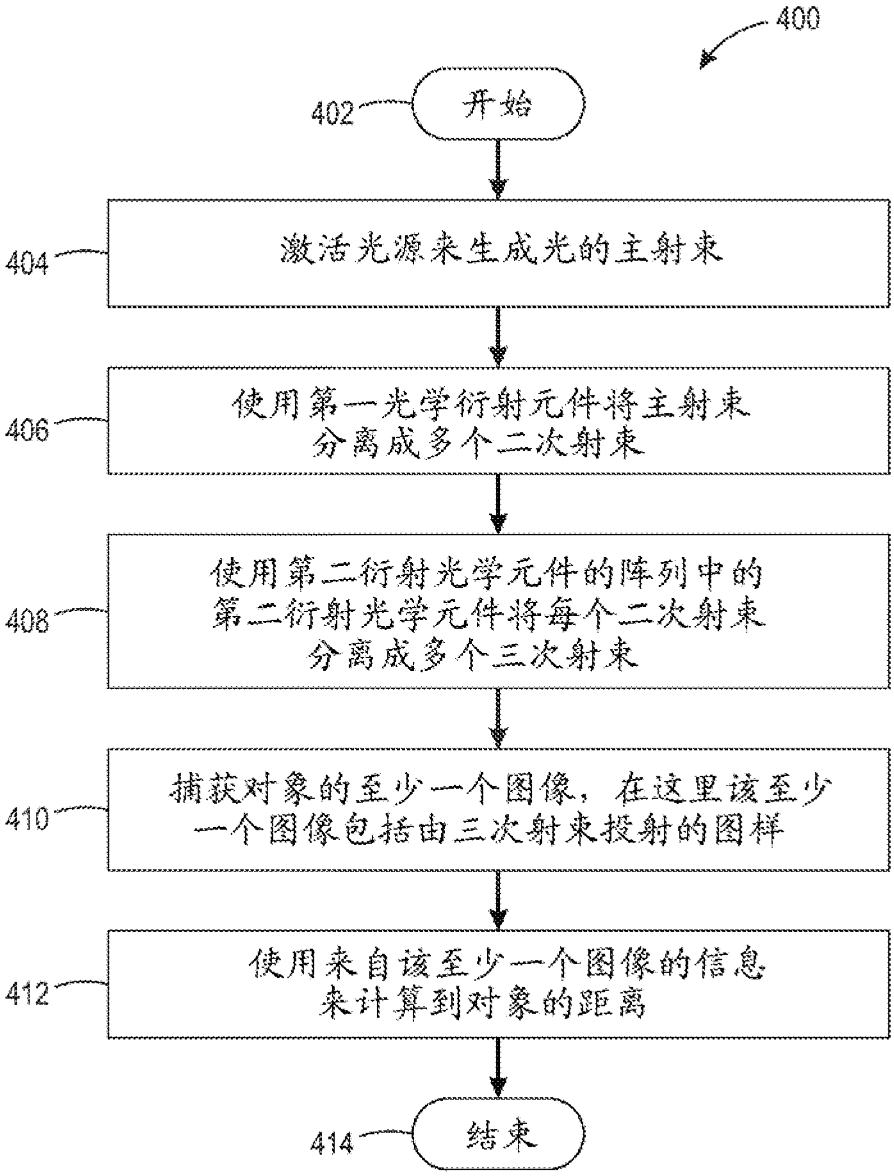

400
402
开始
404
激活光源来生成光的主射束
406
使用第一光学衍射元件将主射束
分离成多个二次射束
408
使用第二衍射光学元件的阵列中的
第二衍射光学元件将每个二次射束
分离成多个三次射束
410
捕获对象的至少一个图像，在这里该至少
一个图像包括由三次射束投射的图样
412
使用来自该至少一个图像的信息
来计算到对象的距离
414
结束

图 4

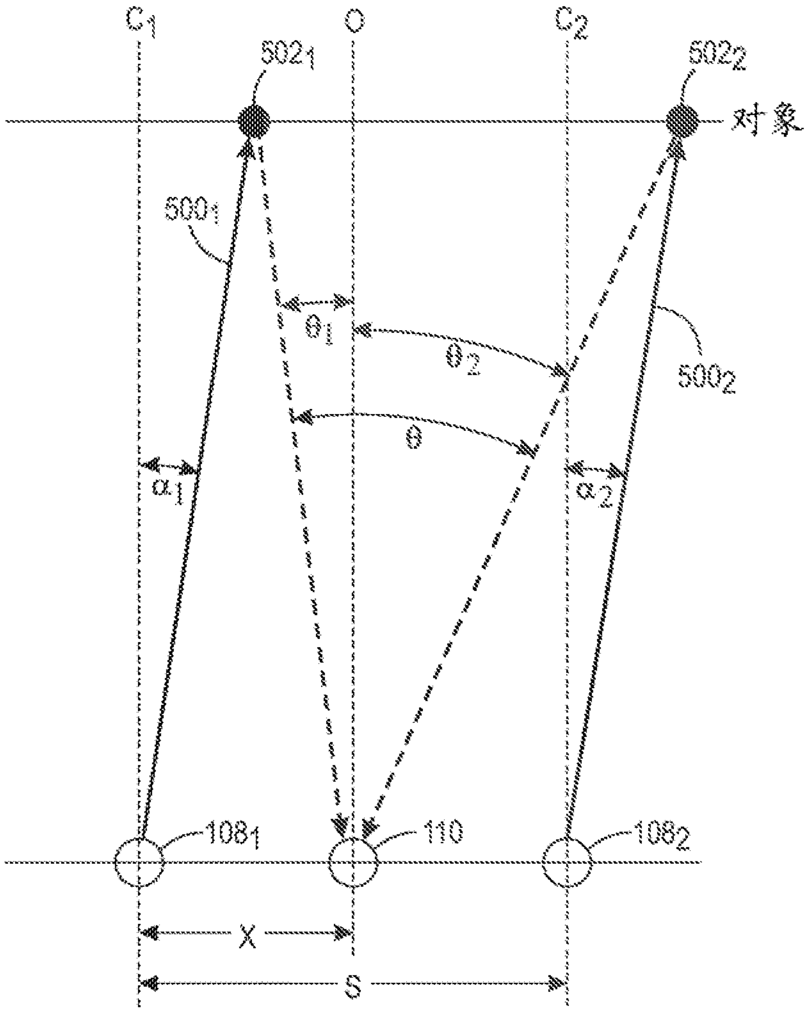
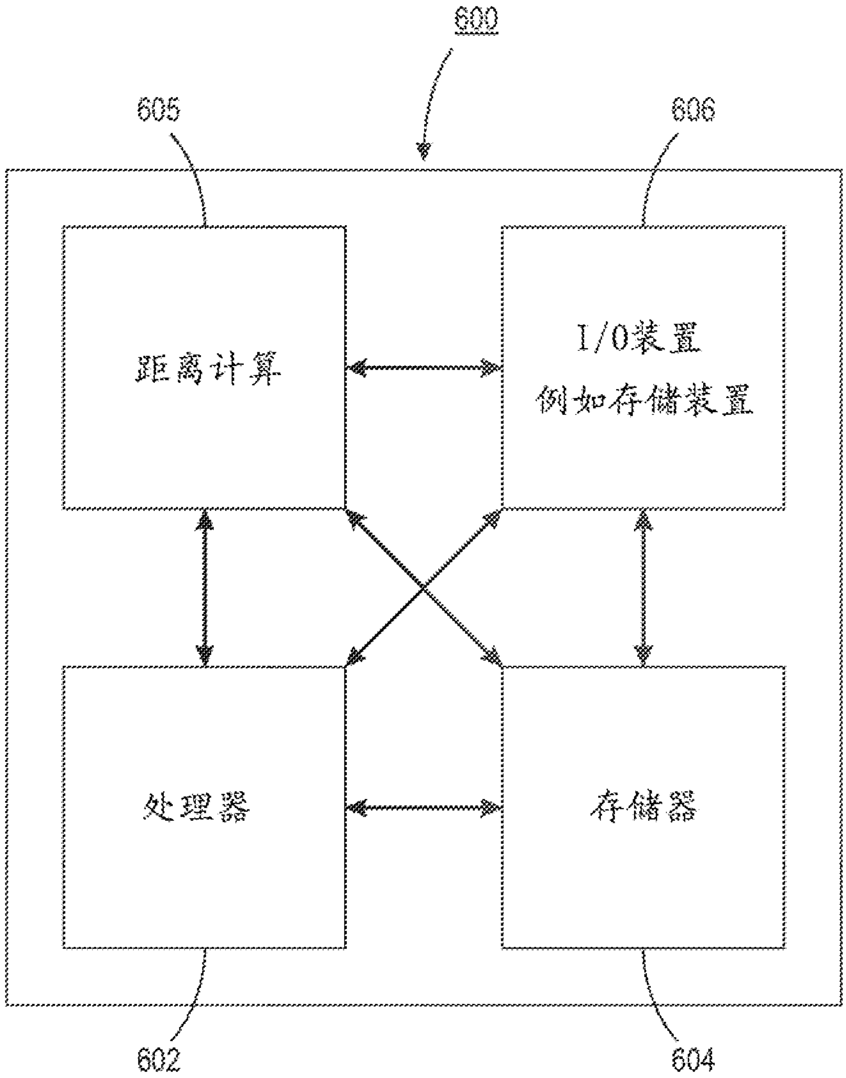
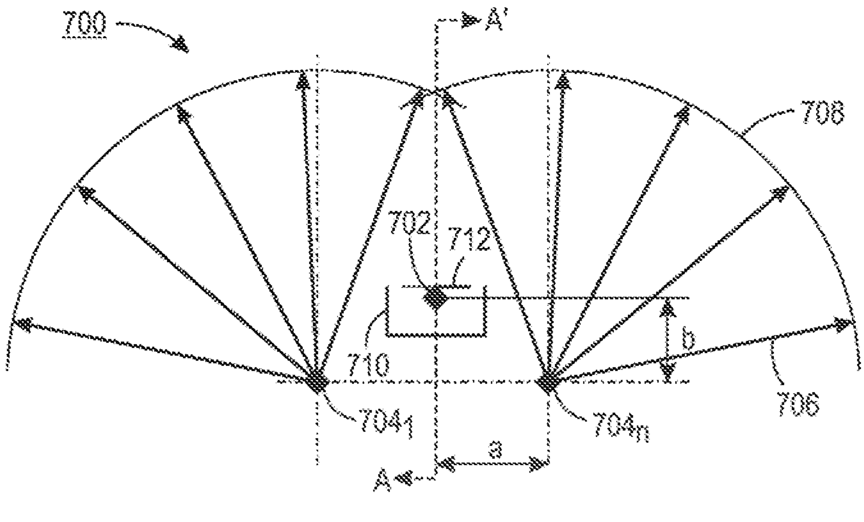


图 5



600
605
606
距离计算
I/O装置
例如存储装置
处理器
存储器
602
604

图 6



700
A'
708
702
712
710
b
706
704_1
704_n
a
A

图 7A

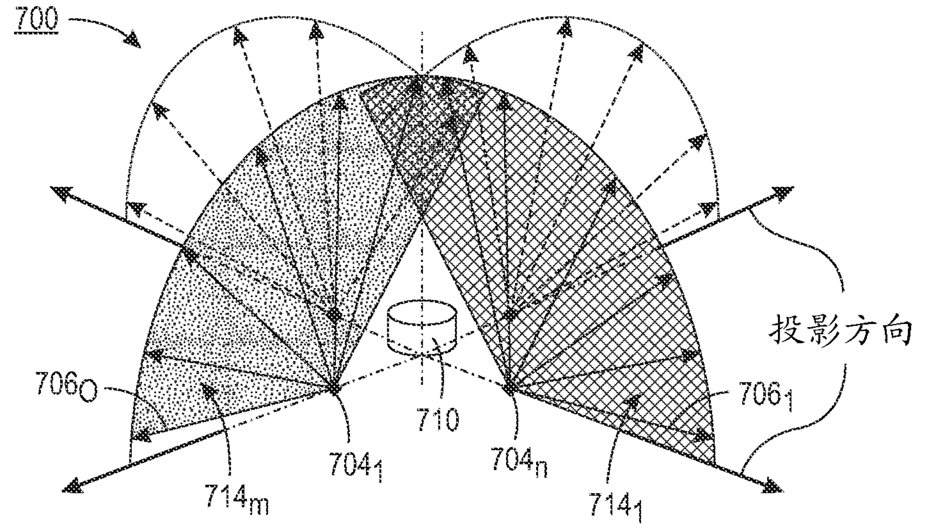

700
投影方向
706O
7061
710
7041
704n
714m
7141

图 7B

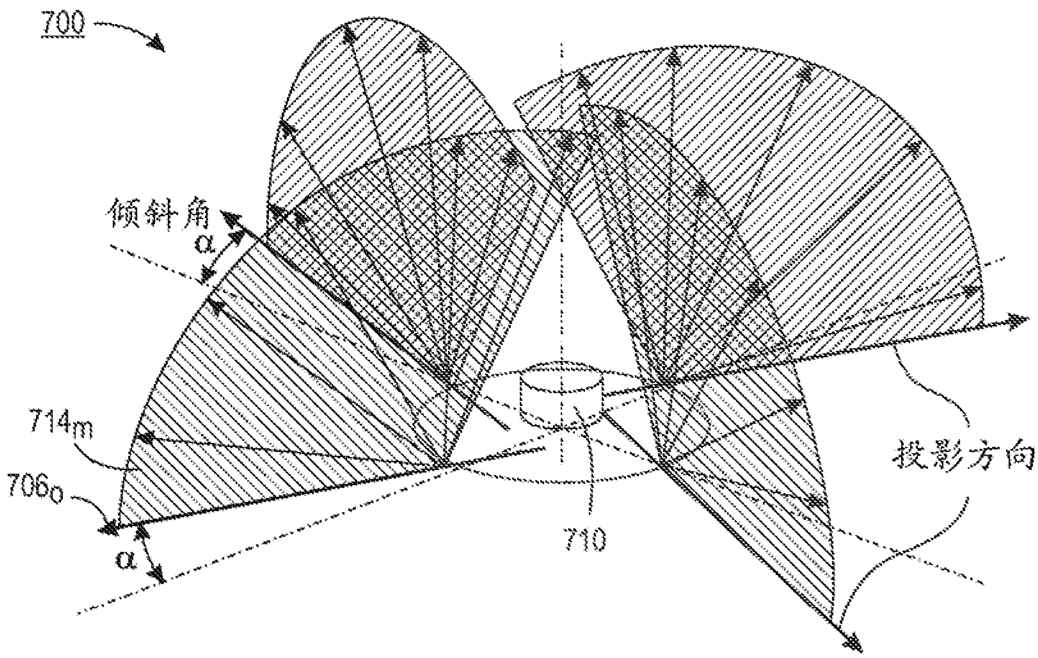

700
倾斜角
α
714m
706o
α
投影方向
710

图 7C

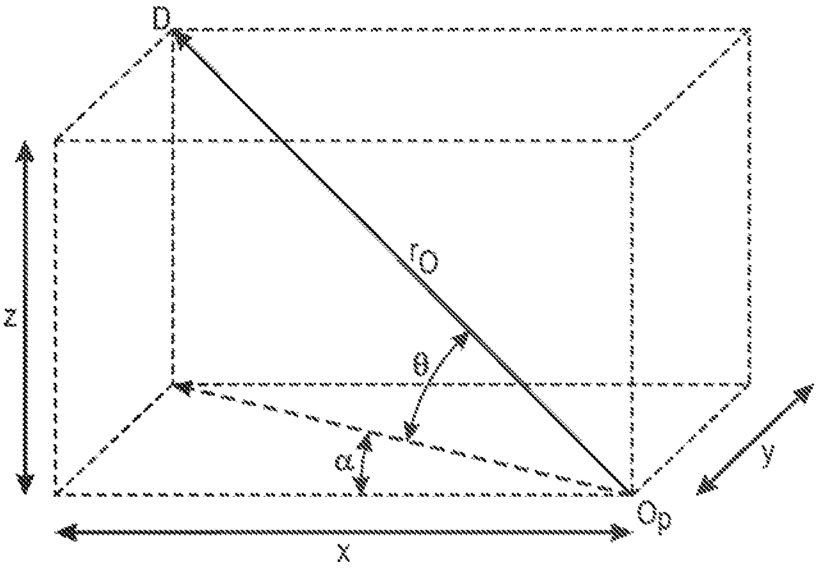


图 8A

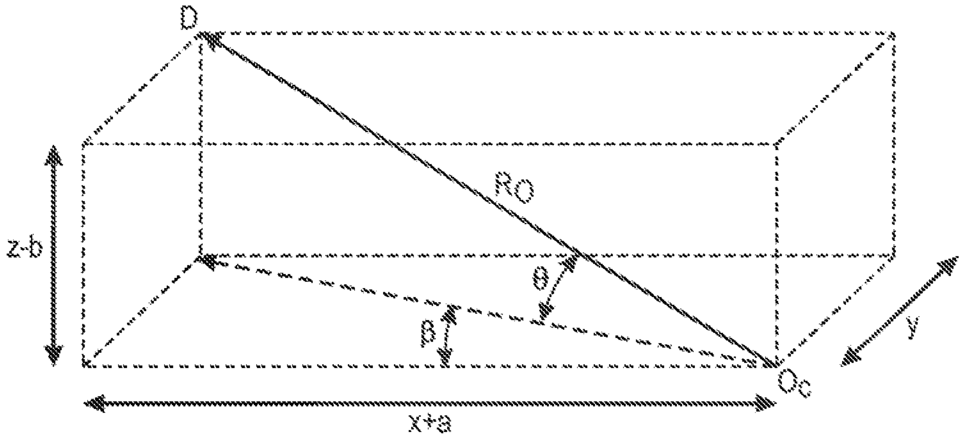


图 8B

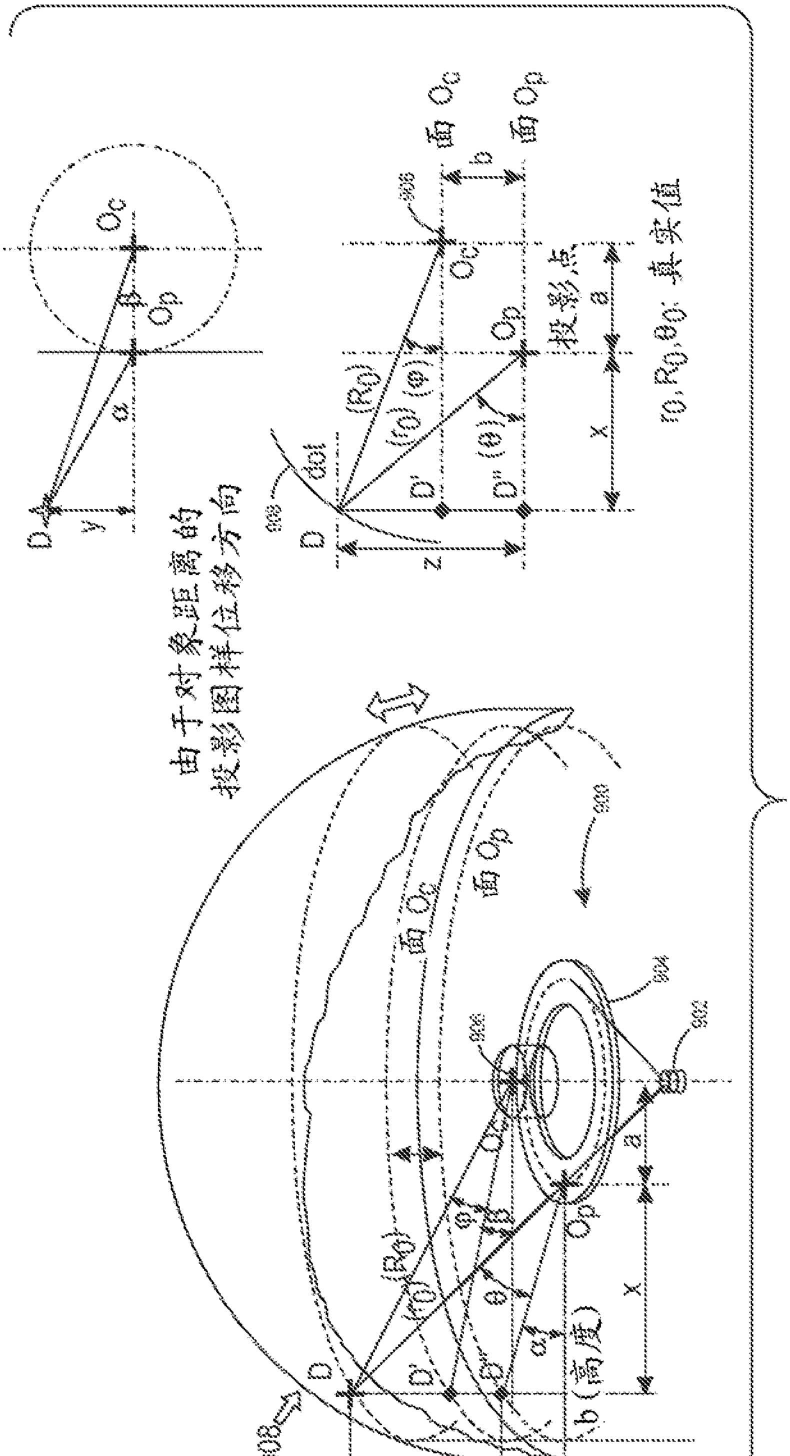


图 9

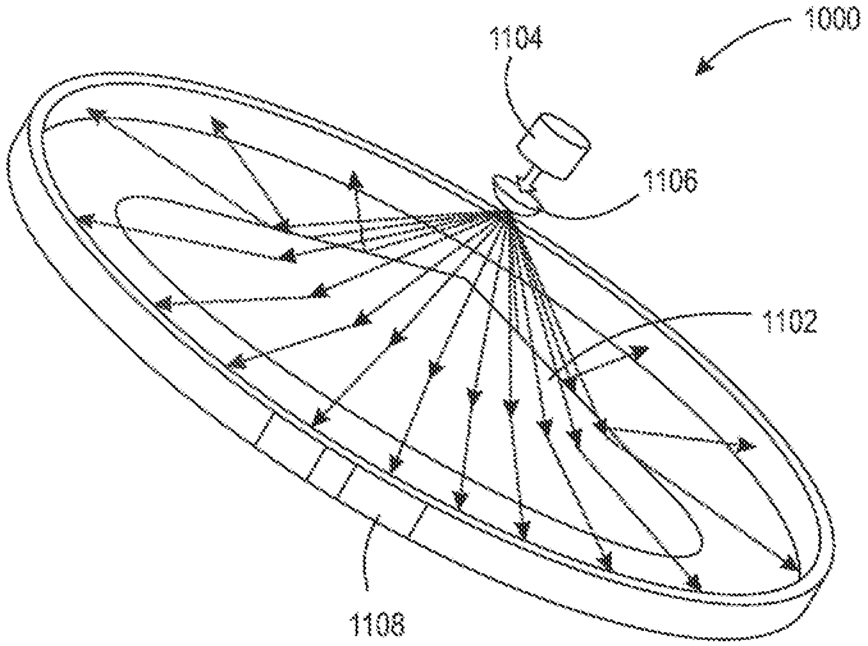


图 10A

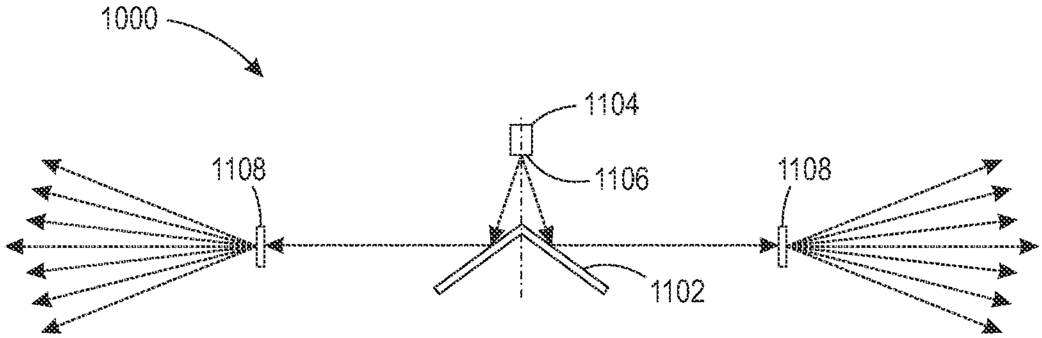


图 10B

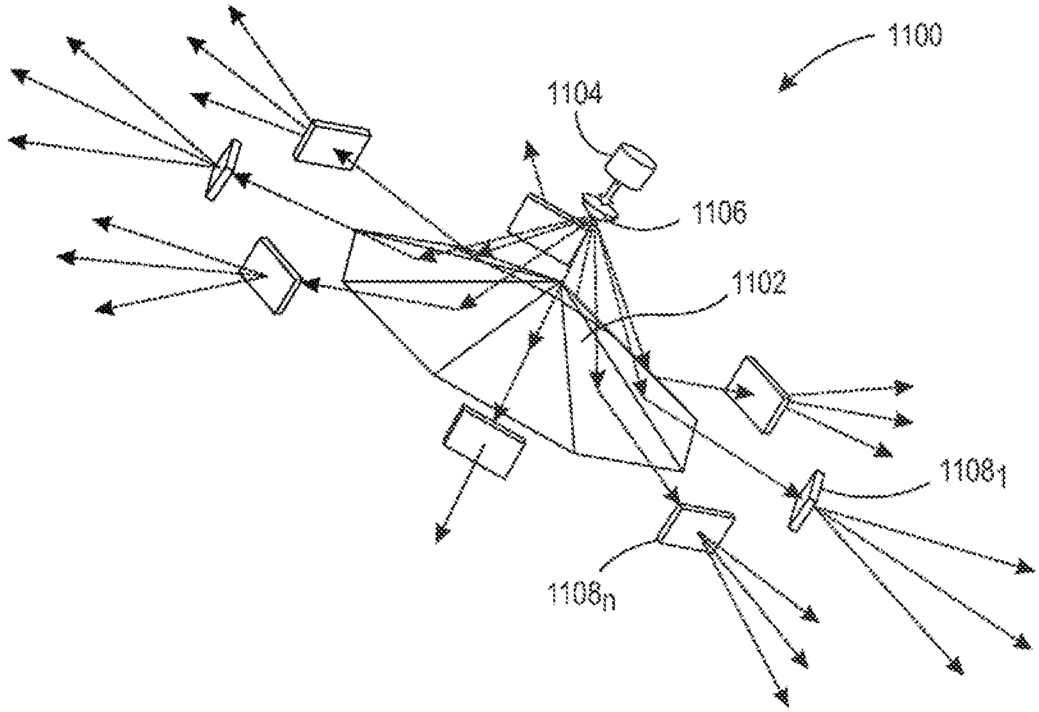

1100
1104
1106
1102
1108_1
1108_n

图 11A

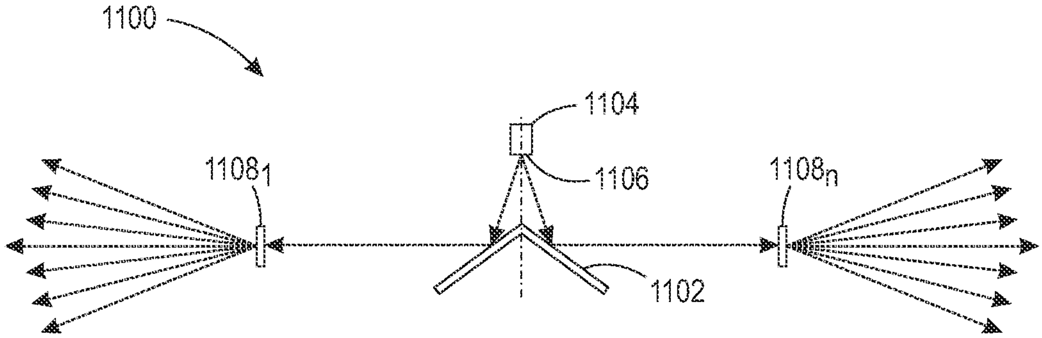

1100
1104
1108_1
1106
1108_n
1102

图 11B