(54) Title of the Invention: Image-stitching for dimensioning

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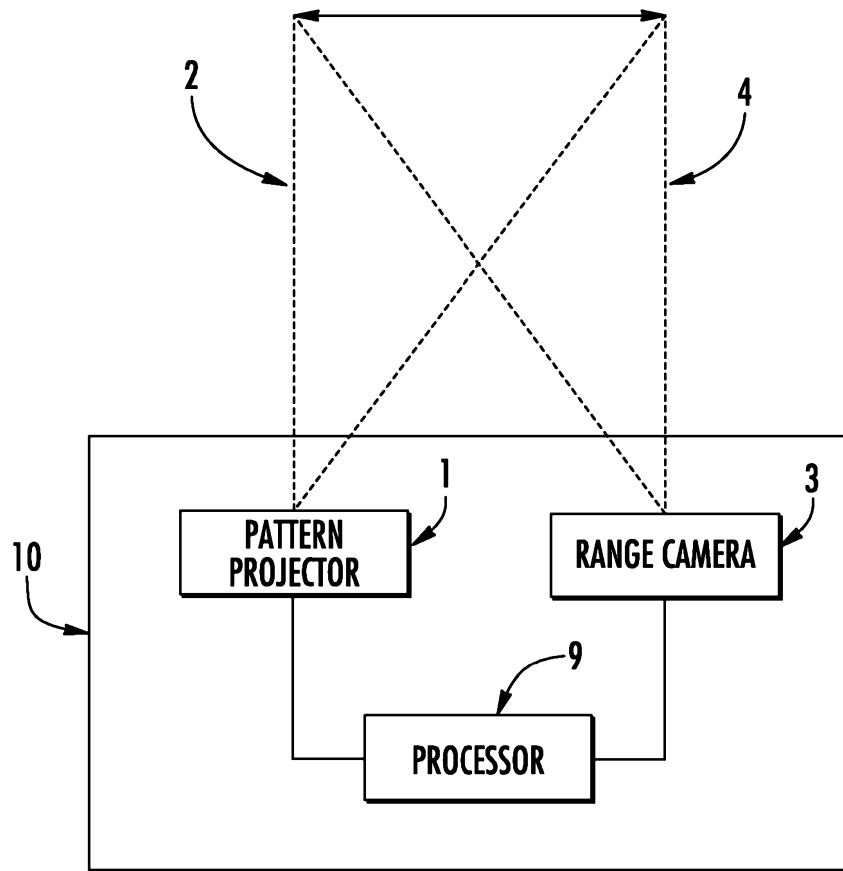   **Jingquan Li**
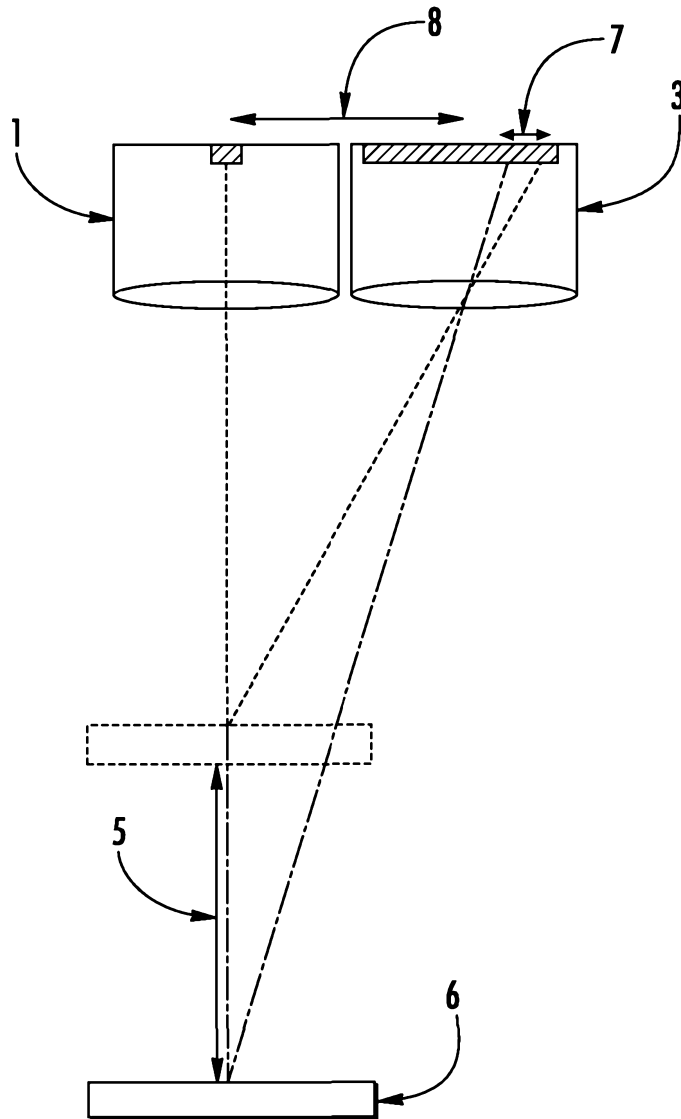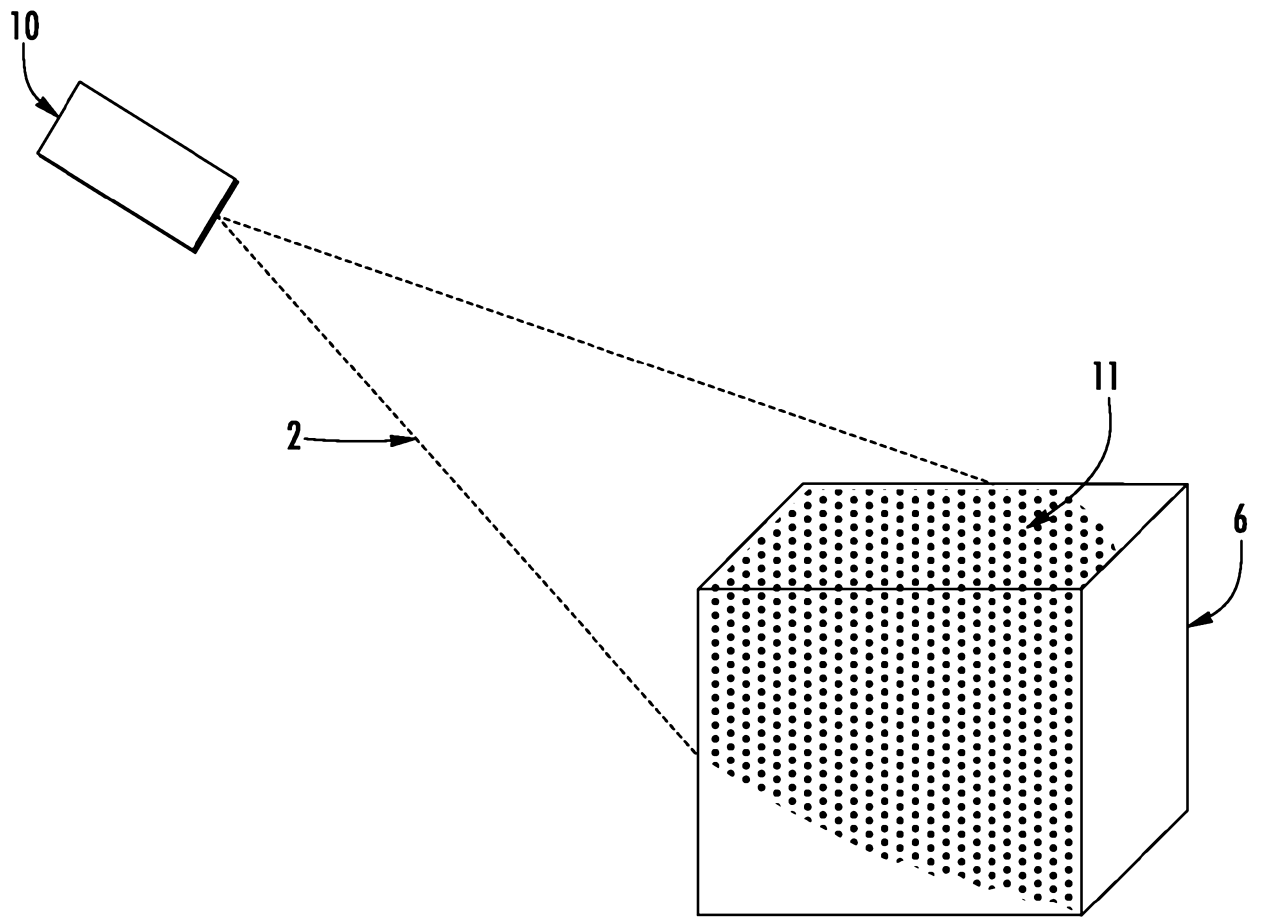
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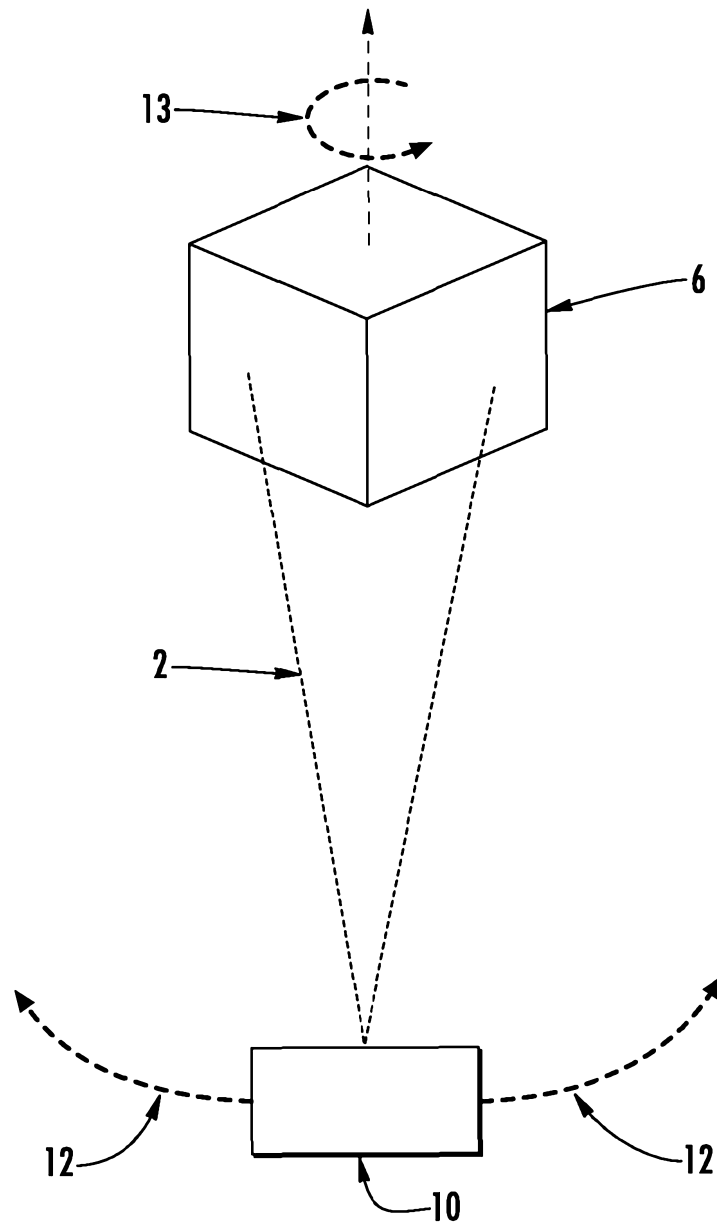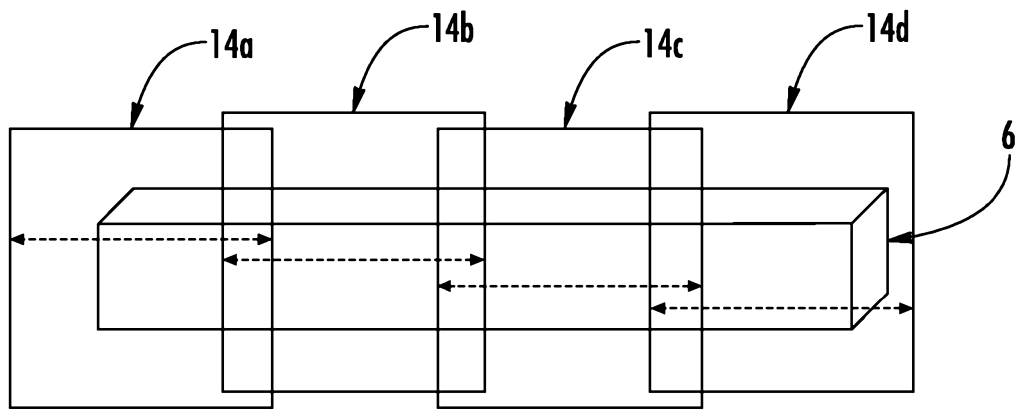
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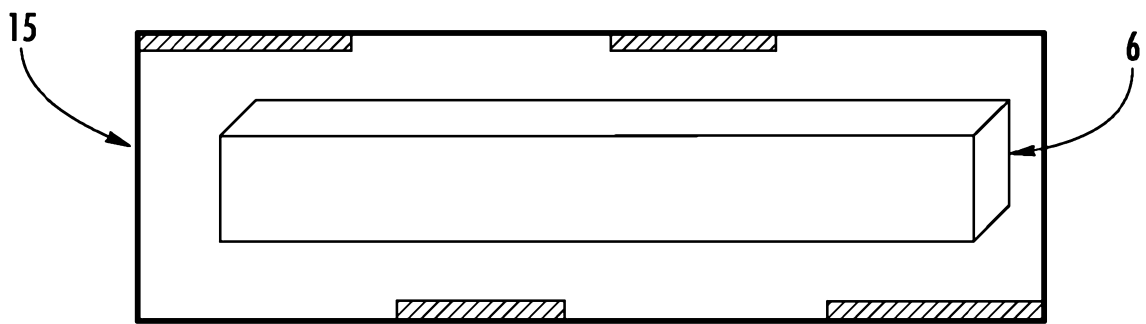GB 2564794 B

FIG. 1

FIG. 2

FIG. 3
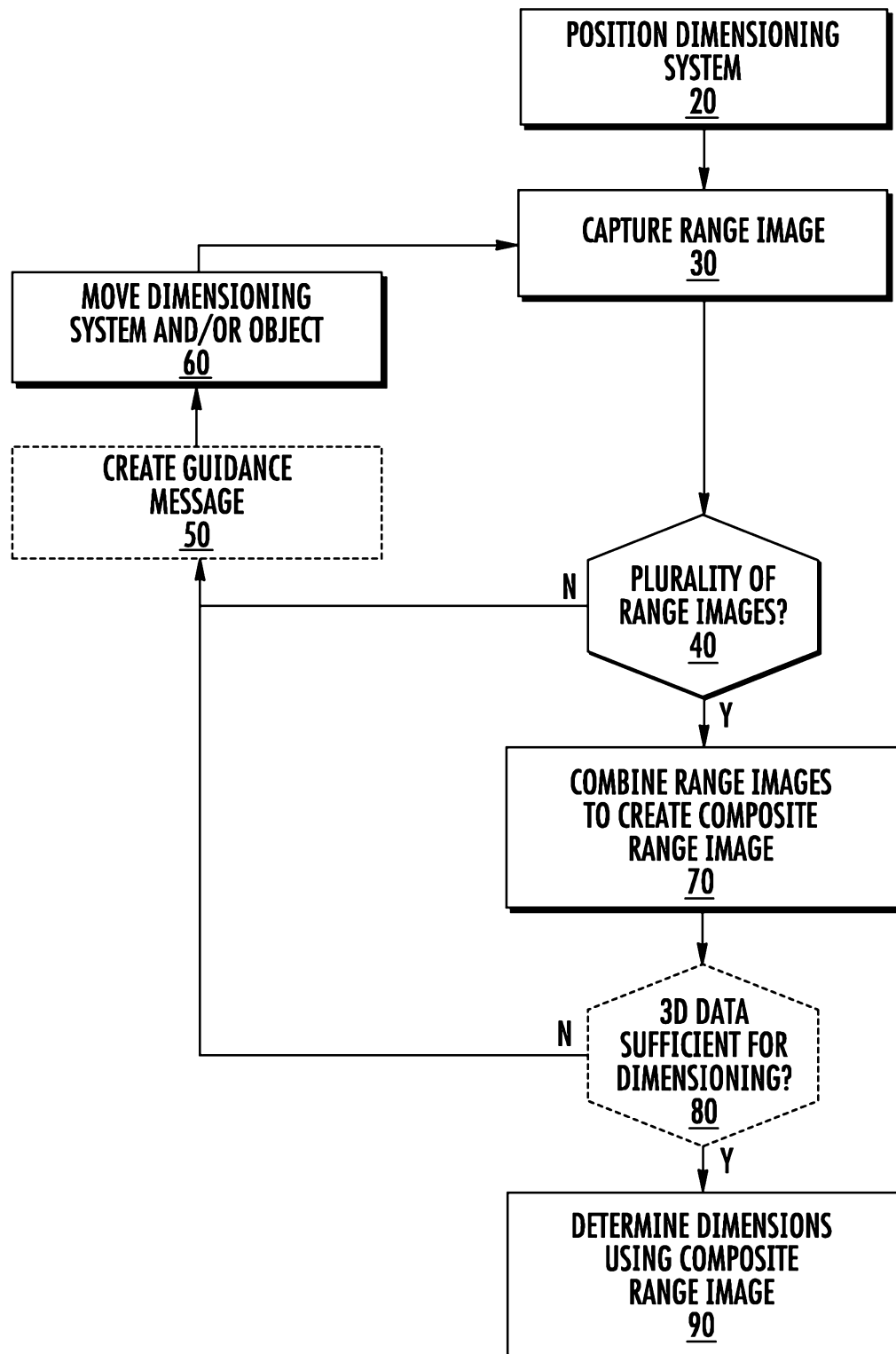
FIG. 4

FIG. 5A

FIG. 5B

FIG. 6

IMAGE-STITCHING FOR DIMENSIONING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Patent Application Ser. No. 62/062,175 for *System and Methods for Dimensioning*, (filed October 10, 2014).

FIELD OF THE INVENTION

[0002] The present invention relates to systems for determining an object's physical dimensions (i.e., dimensioning systems) and, more specifically, to a dimensioning system that uses image-stitching to acquire the data necessary for dimensioning.

BACKGROUND

[0003] Determining an item's dimensions is often necessary as part of a logistics process (e.g., shipping, storage, etc.). Physically measuring objects, however, is time consuming and may not result in accurate measurements. For example, in addition to human error, measurement errors may result when measuring irregularly shaped objects or when combining multiple objects into a single measurement. As a result, dimensioning systems have been developed to automate, or assist with, this measurement.

[0004] A dimensioning system typically senses an object's shape/size in three-dimensions (3D) and then uses this 3D information to compute an estimate of an object's dimensions (e.g., volume, area, length, width, height, etc.). In addition, for irregular objects (or multiple objects), the dimensioning system may compute the dimensions of a minimum bounding box (MVBB) that contains the object (or objects).

[0005] The dimensioning system may sense an object by projecting a light pattern (i.e., pattern) into a field-of-view. Objects within the field-of-view will distort the

appearance of the light pattern. The dimensioning system can capture an image of the reflected light-pattern and analyze the pattern distortions in the captured image to compute the 3D data necessary for dimensioning.

[0006] Accurate dimensioning requires images with (i) high pattern visibility and (ii) high pattern density. In some cases, however, the pattern is hard to resolve. For example, the pattern may be obscured by the shape of the object, or by the object's color (i.e., reflectivity). In other cases, the lighting in the environment may obscure the pattern in the captured images (e.g., under exposure or over exposure). In still other cases, the object may be larger than the dimensioning system's field-of-view. While moving the dimensioning system away from the object may help fit the object within the field-of-view, this comes at the expense of pattern density because the projected pattern spreads as the range between the object and the dimensioning system is increased.

[0007] In digital photography image-stitching is the process of combining images to produce a larger, high-resolution image. Image-stitching may be applied to dimensioning in order to increase the dimensioning system's field-of-view without sacrificing pattern density. In addition, image-stitching can help to resolve a pattern that was obscured in a single image. Therefore, a need exists for image-stitching images acquired by a dimensioning system in order to better measure objects.

<u>S̲UMMARY</u>

[0008] The invention is set out in accordance with the appended claims. Accordingly, in one aspect, the present invention embraces a method for dimensioning an object. In the method, a dimensioning system is positioned so that at least a portion of an object is contained in the dimensioning

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system's field-of-view. The dimensioning system then captures
a first range image of the field-of-view. After the first
range image is captured, either the dimensioning system or the
object is moved so that the dimensioning system's field-of-
view contains a different portion of the object. Then, a
second range image is captured. This process of moving the
dimensioning system (or the object) and capturing a range
images is repeated until a plurality of range images are
captured. The plurality of range images are then combined to
create a composite range-image. The dimensions of the object
are then determined using the composite range-image.

[0009] In a possible embodiment of the method, capturing a
range image includes (i) using a pattern projector to project
a light pattern into the field-of-view, (ii) capturing an
image of the reflected light-pattern using a range camera, and
(iii) generating 3D data from the image of the reflected
light-pattern.

[0010] In another possible embodiment of the method, capturing
a range image includes (i) using a pattern projector to
project a light pattern into the field-of-view, (ii) capturing
an image of the reflected light-pattern using a range camera,
and (iii) generating 3D data from the image of the reflected
light-pattern so that the plurality of range images contain 3D
sufficient for dimensioning the object. For example, 3D data
sufficient for dimensioning may imply that 3D data is
collected from all surfaces of the object. Alternatively, 3D
data sufficient for dimensioning may imply that the 3D data
from a surface of the object has no gaps (i.e., no missing
areas) in the reflected light-pattern.

[0011] In another exemplary embodiment of the method, the
dimensioning system is handheld.

[0012] In another exemplary embodiment of the method, audio
and/or visual message are generated to guide the user in
performing the movement of the dimensioning system or the

object. For example, these audio and/or visual messages can include instructions for the user to (i) move the dimensioning system (or the object) in a particular direction, (ii) move the dimensioning system (or the object) at a particular speed, and/or (iii) cease moving the dimensioning system (or the object).

[0013] In another exemplary embodiment of the method, moving either the dimensioning system or the object includes an automatic movement of the dimensioning system (or the object).

[0014] In another exemplary embodiment of the method, combining the plurality of range images to create a composite range-images includes image-stitching the plurality of range images. In one possible embodiment, the image-stitching includes simultaneous localization and mapping (SLAM).

[0015] In another aspect, the present invention embraces a dimensioning system that includes (i) a pattern projector, (ii) a range camera, and (iii) a processor that is communicatively coupled to the pattern projector and the range camera. The pattern projector is configured to project a light pattern onto an object, while the range camera is configured to capture an image of the reflected light-pattern. The range camera uses the reflected light-pattern to generate 3D data and uses the 3D data to create a range image.

[0016] The dimensioning system's processor is configured by software to trigger the range camera to capture a plurality of range images and combine the plurality of captured range images to form a composite range-image. Then, using the composite range-image, the processor calculates the dimensions of the object.

[0017] In an exemplary embodiment of the dimensioning system, the plurality of range images are captured as the spatial relationship between the dimensioning system and the object is changed. For example, in one embodiment, the dimensioning system is handheld and a user can move the dimensioning system

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so that each range image in the plurality of range images includes 3D data from a portion of the object, and the composite range-image includes 3D data from the entire object. In some embodiments, the processor is further configured by software to gather tracking/mapping information as the spatial relationship between the range camera and the object is changed. The tracking/mapping information can be used, in some embodiments, to generate messages to help a user change the spatial relationship between the range camera and the object. These messages may be instructions to (i) move the dimensioning system or the object in a particular direction, (ii) move the dimensioning system or the object at a particular speed, and/or (iii) cease moving the dimensioning system or the object. After the plurality of range images are captured, the processor can be configured by software to create a composite range-image by image-stitching the range images using the tracking/mapping information. In a possible embodiment, the plurality of range images for image-stitching have partially overlapping fields of view.

[0018] 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

[0019] Figure 1 schematically depicts a block diagram of a dimensioning system according to an embodiment of the present invention.

[0020] Figure 2 graphically depicts the principle of sensing three dimensions using a spatially offset pattern projector and range camera according to an embodiment of the present invention.

[0021] Figure 3 graphically depicts an implementation of a dimensioning system's pattern projector according to an embodiment of the present invention.

[0022] Figure 4 graphically depicts the movement of either the dimensioning system and/or the object according to an embodiment of the present invention.

[0023] Figure 5a graphically depicts a plurality of images, wherein each constituent image contains a portion of an object.

[0024] Figure 5b graphically depicts a composite image of the object formed by image-stitching the constituent images shown in Figure 5a.

[0025] Figure 6 graphically depicts a flow diagram illustrating a method for dimensioning an object according to an embodiment of the present invention.

Detailed Description

[0026] The present invention embraces the use of image-stitching to create a composite range-image for dimensioning. Some advantages of using composite images for dimensioning are (i) better pattern coverage of an irregular object or group of objects, (ii) greater accuracy (i.e., higher pattern density), and (iii) immunity to lighting effects, such as shadows or bright reflections.

[0027] An exemplary dimensioning system is shown in Figure (Fig.) 1. The dimensioning system 10 includes a pattern projector 1 that is configured to project a light (e.g., infrared light) pattern into a field-of-view 2. The light pattern typically comprises points of light arranged in a pattern (i.e., point cloud). The points of light may be (i) sized identically or differently and (ii) may be arranged in some order or pseudo-randomly. The pattern projector may create the light pattern using a light source (e.g., laser,

LED, etc.), a pattern creator (e.g., a mask, a diffractive optical element, etc.), and one or more lenses.

[0028] The dimensioning system 10 also includes a range camera 3 configured to capture an image of the projected light pattern that is reflected from the range camera's field-of-view 4. The field-of-view of the range camera 4 and the field-of-view of the pattern projector 2 should overlap but may not necessarily have identical shapes/sizes. The range camera 3 includes one or more lenses to form a real image of the field-of-view 4 onto an image sensor. Light filtering (e.g., infrared filter) may be also be used to help detect the reflected pattern by removing stray light and/or ambient light. An image sensor (e.g., CMOS sensor, CCD sensor, etc.) is used to create a digital image of the light pattern. The range camera may also include the necessary processing (e.g. DSP, FPGA, ASIC, etc.) to obtain 3D data from the light pattern image.

[0029] As shown in Fig. 2, the pattern projector 1 and the range camera 3 are spatially offset (e.g., stereoscopically arranged). The spatial offset 8 allows for changes in the range 5 of an object 6 to be detected as an image offset 7 on the range camera's image sensor. The spatial offset 8 may be adjusted to change the image offset 7 to change the resolution at which range differences 5 may be detected. In this way, image offsets in the point-cloud pattern may be converted into 3D data for objects within the dimensioning system's field-of-view.

[0030] The 3D data includes range values for each point of light in the point-cloud image. Further, range values between the points of light in the point-cloud image may be interpolated to create what is known as a range image. A range image is a gray scale image in which each pixel value in the image corresponds to an estimated range between the dimensioning system and a point in the field-of-view. The

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range camera may output 3D data in the form of point-cloud images or range images.

[0031] A range image may be analyzed using software algorithms running on the dimensioning system's processor 9 to detect objects and determine the object's dimensions. In some cases these algorithms may include steps to create a minimum bounding box (MVBB), which is a computer model of a box that surrounds an object (e.g., an irregularly shaped object) or a collection of objects (e.g., multiple boxes on a pallet). In this case, the dimensioning system may return the dimensions of the MVBB.

[0032] Accurate dimensioning requires high-quality images of the reflected pattern (i.e., point-cloud images). A high quality point-cloud image is one in which the points of light in the pattern are visible on a plurality of the object's surfaces. Low quality point-cloud images may result from a variety of circumstances. For example, the imaged pattern may not be visible one or more surfaces (e.g., surfaces that are blocked from the pattern projector) or fall outside the field-of-view of either the pattern projector and/or the range camera. In another example, the light pattern may be partially visible on a surface and/or lack sufficient pattern density (i.e., the number of visible points of light on the surface). In yet another example, the lighting (e.g., glare, shadows) in the object's environment and/or the object's reflectivity (e.g., dark objects) may adversely affect the visibility of the light pattern.

[0033] Fig. 3 graphically depicts a dimensioning system 10 projecting a light pattern 11 onto an object 6. Here the object is larger than the pattern projector's field-of-view 2. As a result, portions of the object do not intersect with the projected light-pattern 11. Since dimensioning relies on sensing the image offset of the projected light-pattern, no 3D

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data can be created for the portions of the object that do not intersect with the projected light-pattern 11.

[0034] The present invention mitigates or solves these problems by capturing a plurality of point-cloud images (or range images) from different perspectives and then combining the plurality of point-cloud images (or range images) into a composite point-cloud image (or range image).

[0035] Fig. 3 illustrates how the movement of the dimensioning system 10 and/or the object 6 may help capture (i.e., sense, sample, etc.) 3D data. The movement allows for the capture of 3D data from more portions of the object than could be obtained with a single range image having a field-of-view 2 smaller than the object 6.

[0036] Range images may be captured during the movement and then combined to form a composite range-image. The composite range-image has 3D data from more points on the object. For example, all sides of an object may be sampled during the moving process to obtain 3D data from the entire object. Further, gaps in the pattern (i.e., missing areas in the pattern) may be filled in using this technique.

[0037] In one possible embodiment, the movement of the dimensioning system and/or the object is automatic and does not require user participation. In this embodiment, the dimensioning system may be coupled to movement devices (e.g., actuators, motors, etc.) that adjust the spatial relationship between the dimensioning system and the object. In one example, the object 6 may be placed in a measurement area and the dimensioning system 10 may be moved around the object 12 to collect range images from various perspectives as shown in Fig 4. In another example, a fixed dimensioning system may collect range images as an object 6 is rotated (e.g., on a motorized turntable) 13 as shown in Fig. 4. In these cases, position information may be obtained from the movement device and used to help combine the range images.

[0038] In another possible embodiment, the movement of the dimensioning system and/or the object is performed by a user. Here messages (e.g., audio, visual, etc.) may be generated by the dimensioning system's processor and conveyed to a user interface (e.g., screen, indicator lights, speaker, etc.). The user may follow the instructions provided by the messages to move the dimensioning-system/ object. The instructions may include messages to help a user know (i) how far to move the dimensioning-system/object, (ii) how fast to move the dimensioning-system/object, (iii) to move the dimensioning system/object to a particular location, and (iv) how long to continue moving the dimensioning-system/object (e.g., when to stop moving). For example, the dimensioning system may be handheld and the user may move the dimensioning system to change perspective. In this case, the dimensioning system may be configured to gather tracking information (e.g., sense its position and orientation within the environment) to help combine the range images.

[0039] In general, the dimensioning system may be moved in a variety of ways as the range images are captured. In some cases, however, this movement may have certain requirements to facilitate combining. For example, movements may be limited to movements having a constant range between the dimensioning system and the object, as changes in range can affect the image size of the light-pattern/object. In another example, the movement may be limited to a certain path having a particular starting point and ending point. This path may be determined using an expected object size/shape.

[0040] The requirements for movement may be reduced through the use of simultaneous localization and mapping (SLAM). SLAM is a computer algorithm that uses images (e.g., range images) of an environment to update the position of the imager (e.g., dimensioning system). When moving a dimensioning-system, for example, SLAM algorithms may detect features (i.e., landmarks)

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in a captured range image and then compare these landmarks to landmarks found in previously captured range images in order to update the position of the dimensioning system. This position information may be used to help combine the range images.

[0041] Combining range images is typically achieved using image-stitching. Image-stitching refers to computer algorithms that transform, register, and blend a plurality of constituent images to form a single composite image. The image-stitching algorithms may first determine an appropriate mathematical model to relate the pixel coordinates for constituent images to the pixel coordinates of a target composite-image surface (e.g., plane, cylinder, sphere, etc.). This involves transforming (e.g., warping) the images to the target composite-image surface. The transformed images may then registered to one another (e.g., using feature detection and mapping) and merged (e.g., blended) to remove edge effects.

[0042] The process and results of image-stitching are illustrated in Fig. 5a and Fig. 5b. As shown in Fig. 5a, four constituent images 14a, 14b, 14c, 14d of an object 6 are captured. Each of the four images contains a different portion of the object 6. Fig 5b illustrates the result of image-stitching the four constituent images. The composite image 15 contains the entire object 6.

[0043] While range images have pixels to representing range instead of reflected light, they are like conventional digital images in most other regards. As such, the principles of image-stitching described thus far may be applied equally to range images (or point-cloud images).

[0044] Figure 6 graphically depicts a flow diagram illustrating a method for dimensioning an object using image-stitching. The method begins with positioning 20 a dimensioning system so that at least a portion on an object is

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contained within the dimensioning system's point-of-view and capturing 30 a range image. The dimensioning system and/or the object is then moved 60 so that another portion of the object is within the field-of-view and another range image is captured 30. This process of moving and capturing is repeated until a plurality of range images is captured 40. The number of range images in the plurality of range images may be a predetermined number or may be determined based on the motion of the dimensioning system/object. The plurality of range images are then combined 70 to form a composite range-image, and the composite range-image is used to dimension 90 the object.

[0045] In one exemplary embodiment, the dimensioning system may create messages 50 to guide the movement of the dimensioning system and/or the object as described previously.

[0046] In another exemplary embodiment, the dimensioning system may create or update the composite range-image in real time. In this case, the dimensioning system may be able to examine the latest composite range-image to determine if there is 3D data sufficient for dimensioning (i.e., if a sufficient number of range images have been acquired) 80. If not, the dimensioning system may create messages to help the user move and capture range images so as to gather the missing or incomplete 3D data.

[0047] In the specification and/or figures, typical embodiments of the invention have been disclosed. The present invention is not limited to such exemplary embodiments. The use of the term "and/or" includes any and all combinations of one or more of the associated listed items. The figures are schematic representations and so are not necessarily drawn to scale. Unless otherwise noted, specific terms have been used in a generic and descriptive sense and not for purposes of limitation.

CLAIMS:

1.   A method for dimensioning an object with a dimensioner, the method comprising:

projecting, using a pattern projector, a light pattern on a portion of at least one object in a field of view of the dimensioner;

capturing, using a range camera, a range image of the field-of-view, wherein each pixel of the range image represents a distance from the range camera to a respective point in the range camera's field-of-view;

capturing a plurality of subsequent range images with the range camera, each range image capturing a different portion of the at least one object in the field of view of the dimensioner;

combining the plurality of range images to create a composite range-image;

creating a bounding box that surrounds at least one object; and

computing the dimensions of the bounding box from the composite range-image;

wherein the composite range-image is a two-dimensional image in which pixel values correspond to range.

2.   The method according to claim 1, wherein the dimensioner is coupled to movement devices to adjust the spatial relationship between the dimensioner and the object.

3.   The method according to claim 1, wherein the capturing, using the range camera, the range image of the field-of-view comprises:

capturing, using the range camera, an image of the field-of-view, the image comprising a reflected light-pattern; and

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generating 3D data from the image of the reflected light-pattern.

4.   The method according to claim 3, wherein the plurality of range images collectively comprise 3D data from all surfaces of the object.

5.   The method according to claim 3, wherein the plurality of range images collectively comprise 3D data from a surface of the object without any gaps in the reflected light-pattern.

6.   The method according to claim 1, wherein the dimensioner is handheld.

7.   The method according to claim 1, comprising moving either the dimensioner or the object, and generating audio and/or visual messages to guide a user to perform the movement.

8.   The method according to claim 7, wherein the messages comprise instructions for the user to take action, and the instructions for the user to take action are selected from the group consisting of instructions to (i) move the dimensioner or the object in a particular direction, (ii) move the dimensioner or the object at a particular speed, and (iii) cease moving the dimensioner or the object.

9.   The method according to claim 1, comprising an automatic movement of the dimensioner or the object.

10.   The method according to claim 1, wherein the combining the plurality of range images to create a composite range-image, comprises:
        image-stitching the plurality of range images.

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11.　The method according to claim 10, wherein the image-stitching comprises simultaneous localization and mapping (SLAM).

12.　A dimensioning system, comprising:

　　a pattern projector configured to project a light pattern onto an object;

　　a range camera configured to (i) capture an image of a reflected light-pattern, (ii) generate 3D data from the reflected light-pattern, and (iii) create a range image using the 3D data, wherein each pixel of the range image represents a distance from the range camera to a respective point in the range camera's field-of-view; and

　　a processor communicatively coupled to the pattern projector and the range camera, wherein the processor is configured by software to:

　　　trigger the range camera to capture a plurality of range images while the range camera's field-of-view contains different portions of the object,

　　combine the plurality of range images into a composite range-image, wherein the composite range-image is a two-dimensional image in which pixel values correspond to range,

　　create a bounding box that surrounds at least one object; and

　　computing the dimensions of the bounding box from the composite range-image;

　　wherein the pattern projector and the range camera are configured to enable the plurality of range images to be captured while the spatial relationship between the dimensioning system and the object is changed such that the range camera's field-of-view contains different portions of the object.

13. The dimensioning system according to claim 12, wherein (i) each range image in the plurality of range images comprises 3D data from a portion of the object, and (ii) the composite range-image comprises 3D data from the entire object.

14. The dimensioning system according to claim 13, wherein the processor is further configured by software to:

gather tracking/mapping information as the spatial relationship between the range camera and the object is changed.

15. The dimensioning system according to claim 14, wherein to combine the plurality of range images into a composite range-image, the processor is configured by software to:

image-stitch the plurality of range images using the tracking/mapping information.

16. The dimensioning system according to claim 15, wherein range images in the plurality of range images have partially overlapping fields of view.

17. The dimensioning system according to claim 16 wherein the processor is further configured to:

use the tracking/mapping information to generate messages to help a user change the spatial relationship between the range camera and the object.

18. The dimensioning system according to claim 17, wherein the messages comprise instructions to (i) move the dimensioning system or the object in a particular direction, (ii) move the dimensioning system or the object at a particular speed, and/or (iii) cease moving the dimensioning system or the object.

19. The dimensioning system according to claim 12, wherein the dimensioning system is handheld.