TITLE 3D Imaging Device and Applications

BRIEF DESCRIPTION OF THE DRAWINGS

[0001] FIG. 1 is a partial perspective diagrammatic front view of the 3D imaging system according to a preferred embodiment of the present invention, showing that the system comprises two light receiving units and one light projecting unit.

[0002] FIG. 2A is the camera geometric relationship when the optical axis is not vertical with the measuring object and has an angle shift, the image plane will also be rotated.

[0003] FIG. 2B is the layout of the camera according to the above preferred embodiment of the present invention following Scheimpflug principle.

[0004] FIG. 3A is an exemplary picture showing a coded pattern taken by the camera 101 when the measuring surface is flat, wherein the code is well-proportioned display on the surface.

[0005] FIG. 3B shows the pattern and the code of FIG. 3A.

[0006] FIG. 3C is an exemplary picture showing an image taken by the camera 101 when there is an irregular objects laying on the measuring area, wherein the code will move according to the trigonometry principle, so the software can detect the Z height of each code point.

[0007] FIG.4 is a display of 3D cloud after decoding the image came from the camera 101 according to the above preferred embodiment of the present invention, wherein each coded point has a height and XY position, so that these points can be displayed in a 3D manner.

[0008] FIG. 5A shows a limitation when there is only one camera being used, wherein the dark area cannot be detected.

[0009] FIG. 5B shows the advantage of using dual camera, wherein the second camera will supplement the dark area of the first camera.

[0010] FIG. 6 is an exemplary picture showing a look-up table for decoding according to the above preferred embodiment of the present invention, wherein the software can get the Z height according to the code position and position shift

[0011] FIG. 7 is an exemplary picture showing how a coded pattern help stereo imaging method to find corresponding point according to the above preferred embodiment of the present invention.

[0012] FIG. 8A is an exemplary picture showing a software UI for the acquisition page according to a preferred embodiment of the present invention.

[0013] Fig. 8B is an exemplary picture showing a point cloud page according to the above preferred embodiment of the present invention.

[0014] FIG. 9 is a work-flow of the 3D imaging software according to the above preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] The following description is disclosed to enable any person skilled in the art to make and use the present invention. Preferred embodiments are provided in the following description only as examples and modifications will be apparent to those skilled in the art. The general principles defined in the following description would be applied to other embodiments, alternatives, modifications, equivalents,

and applications without departing from the spirit and scope of the present invention.

[0016] With the aids of the Figures shown below, the content of techniques, features, and embodiments of the present invention is herein described, so as for the examiners to further understand the present invention.

[0017] Fig.1 illustrates the optical setup of the 3D imaging system according to a preferred embodiment of the present invention, wherein a light projecting unit 200 is used to project a coded image shown in Fig. 3A, and two light receiving units 100A and 100B are used to take the coded image on the measured object respectively. Two methods will be used to decoding the 3D position, wherein a method is decoding the position directly from the code shift, and the other method is stereo imaging.

[0018] To reduce the DOF requirement, the optical axis of camera 101 has an angle with the optical axis of lens 102 according to the Scheimpflug principle shown in Fig.2. The rotation angle lies on the angle of lens 102 with the measuring plane. The camera plane is located at the most ideal imaging plane.

[0019] Trigonometry principle is a basic technology in this 3D imaging system, which is to help the system to easily distinguish the effect of height distribution, where the coded pattern is applied. Fig.3A shows a coded pattern taken by the camera 101 when there is a flat surface at the measuring area. The coded point is displayed as points of black (0) and white (1). When the adjacent points are combined together, a code that received could be like 0000,0001,0010……. Based on such information, the system can identify every point in the measuring area, such as what was shown in Fig. 3B. When there is an object in the measuring area, the coded points will be shifted based on the height of the object, such as what was demonstrated in Fig. 3C that the coded points were shifted on the object.

[0020] After decoding for every coded point position, the points can be displayed in 3D as the example shown in Fig. 4. Each point has x, y, z information, so as to be used for measurement and 3D reconstruction.

[0021] The trigonometry principle needs only one projection and one image sensor, but the shape of the measuring object can sometimes block the view of the camera as showing in Fig. 5A. The system according to the above preferred embodiment of the present invention uses two light receiving units in both sides as showing in Fig. 5B, so as to avoid the above drawback. Most importantly, the two light receiving units can not only be complementary to the blind spots of each other, but also provide two data clouds. Each cloud has 3D information of almost every point, so the system can obtain two position values for mostly every point, which will reduce the random error and noise.

[0022] After the system get the image of the coded pattern on the object, it needs to compare the shift of the code with a look-up table shown in Fig. 6. The look-up table was generated with calibration data. Specifically, for example, a flat surface was placed at different heights for the light receiving units to record the different code positions at those heights. After calibration, the system is able to check the positions of every coded point and compare with the look-up table, so as to easily find the height of each point.

[0023] A feature of the present invention is that the use of two light receiving units has another purpose, which is to also apply a stereo imaging method. The two light receiving units capture the coded points at the same time. As the point is coded, the two image can easily be matched as showing in Fig. 7. Thus the system will have a third 3D cloud which can improve the 3D imaging accuracy. This method will not only capture the coded points but also detect feature points like the prominence and the edge. This will highly increase the integrity of decoding output.

[0024] The software according to the above preferred embodiment of the present invention consists several tab pages for different functions. In the acquisition page a user can see the video of the object, referring to Fig. 8A, if the cameras are connected to a computer. The user can also click an “capture” button to snap shot the images of the object at the same time and save the images to the computer. The user may open the saved images and view them in the acquisition page too. The user can input the stereo point pair by clicking the point in the left image and its corresponding point in the right image as well. The user can then click another button to request the computer to run the program to generate 3D point cloud or depth map. The generated 3D point cloud will be displayed in the point cloud page, referring to Fig. 8B, while the depth map will be displayed in depth map page.

[0025] FIG.9 shows the work-flow of the 3D imaging application according to the above preferred embodiment of the present invention. The application includes the following steps:

[0026] (a) launching the projection on the object;

[0027] (b) adjusting the fixture of the sample for interested area;

[0028] (c) focusing to the top surface of the object;

[0029] (d) capturing the images;

[0030] (e) decoding the images;

[0031] (f) generating point clouds based on triangulation algorithm and stereo vision algorithm;

[0032] (g) merging the point clouds; and

[0033] (h) outputting the result.

[0034] The step (a) is to have an applicable projection be projected on the object that is to be measured, so as to be referred to for measuring the range and other information of the object based on the images taken later. The step (b) is to adjust the fixture of the sample so as to find interested area and make sure these areas are rightly within the scope of measuring. The step (c) is to focus the cameras to the top surface of the object as it is fixed. The step (d) is to capture the images with the cameras. The step (e) is to decode the images taken in the step (d). The step (f) is to use the decoded information to respectively generate point clouds based on triangulation algorithm and stereo vision algorithm. Then the step (g) merges both of these point clouds to obtain a more accurate point cloud and 3D measurement. Lastly, the step (h) is applied to outputting the result from the step (g) by displaying on a monitor of a connected device or other ways, such as sending out an internet message or launching a 3D printing accordingly.

[0035] Specifically, for the perspective of a user, he or she may simply click a “start” icon from the step (d) in the above mentioned software according to the above preferred embodiment of the present invention, so as to have the software automatically conduct the rest of steps to measure and decode according to the images, merge and output 3 points clouds, and display the result with one 3D image.

[0036] The present invention also provides a 3D surface measuring method comprising the steps of:

[0037] (i) irradiating an object to be measured with coded light pattern with the light projecting unit;

[0038] (ii) imaging the object with two light receiving units;

[0039] (iii) displaying the captured images of the object;

[0040] (iv) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

[0041] (v) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

[0042] (vi) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

[0043] (vii) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object; and

[0044] (viii) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

[0045] Besides, the present invention provided a 3D surface measuring non-transitory program adapted for being executed by a processing device, comprising the processing of:

[0046] (I) irradiating an object to be measured with a coded light pattern with the light projecting unit;

[0047] (II) imaging the object with two light receiving units;

[0048] (III) displaying the captured images of the object;

[0049] (IV) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

[0050] (V) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

[0051] (VI) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

[0052] (VII) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object;

[0053] (VIII) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

[0054] One skilled in the art will understand that the embodiment of the present invention as shown in the drawings and described above is exemplary only and not intended to be limiting.

[0055] It will thus be seen that the objects of the present invention have been fully and effectively accomplished. The embodiments have been shown and described for the purposes of illustrating the functional and structural principles of the present invention and is subject to change without departure from such principles. Therefore, this invention includes all modifications encompassed within the spirit and scope of the following claims.

WHAT IS CLAIMED IS:

1. A 3D surface measuring device comprising: two light receiving units and one light projecting unit.

2. The 3D surface measuring device, according to claim 1, wherein said light receiving units are tilted according to Scheimpflug principle.

3. The 3D surface measuring device, according to claim 1, wherein said light projecting unit projects a coded pattern onto the surface of an object to be measured.

4. The 3D surface measuring device, according to claim 1, comprising more than two said light receiving units according to the measurement field of view and the accuracy requirement.

5. The 3D surface measuring device, according to claim 1, wherein said light projecting unit is selected from a group consisting of digital light processing projector, laser projector, and mask projector, wherein said projector connects to a piezoelectric device to conduct translational motion, so as to move the projection image.

6. The 3D surface measuring device, according to any of the claims 1-5, applying stereo imaging technology to improve the device performance, provide additional point cloud, and detect unwanted feature points of prominences and edges.

7. A 3D surface measuring method comprising the steps of:

(i) irradiating an object to be measured with coded light pattern with the light projecting unit;

(ii) imaging the object with two light receiving units;

(iii) displaying the captured images of the object;

(iv) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

(v) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

(vi) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

(vii) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object; and

(viii) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

8. A 3D surface measuring non-transitory program adapted for being executed by a processing device, comprising the processing of:

(I) irradiating an object to be measured with a coded light pattern with the light projecting unit;

(II) imaging the object with two light receiving units;

(III) displaying the captured images of the object;

(IV) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

(V) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

(VI) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

(VII) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object;

(VIII) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

9. A 3D surface measuring method comprising the steps of:

(a) launching the projection on the object;

(b) adjusting the fixture of the sample for interested area;

(c) focusing to the top surface of the object;

(d) capturing the images;

(e) decoding the images;

(f) generating point clouds based on triangulation algorithm and stereo vision algorithm;

(g) merging the point clouds; and

(h) outputting the result.

FIG.1

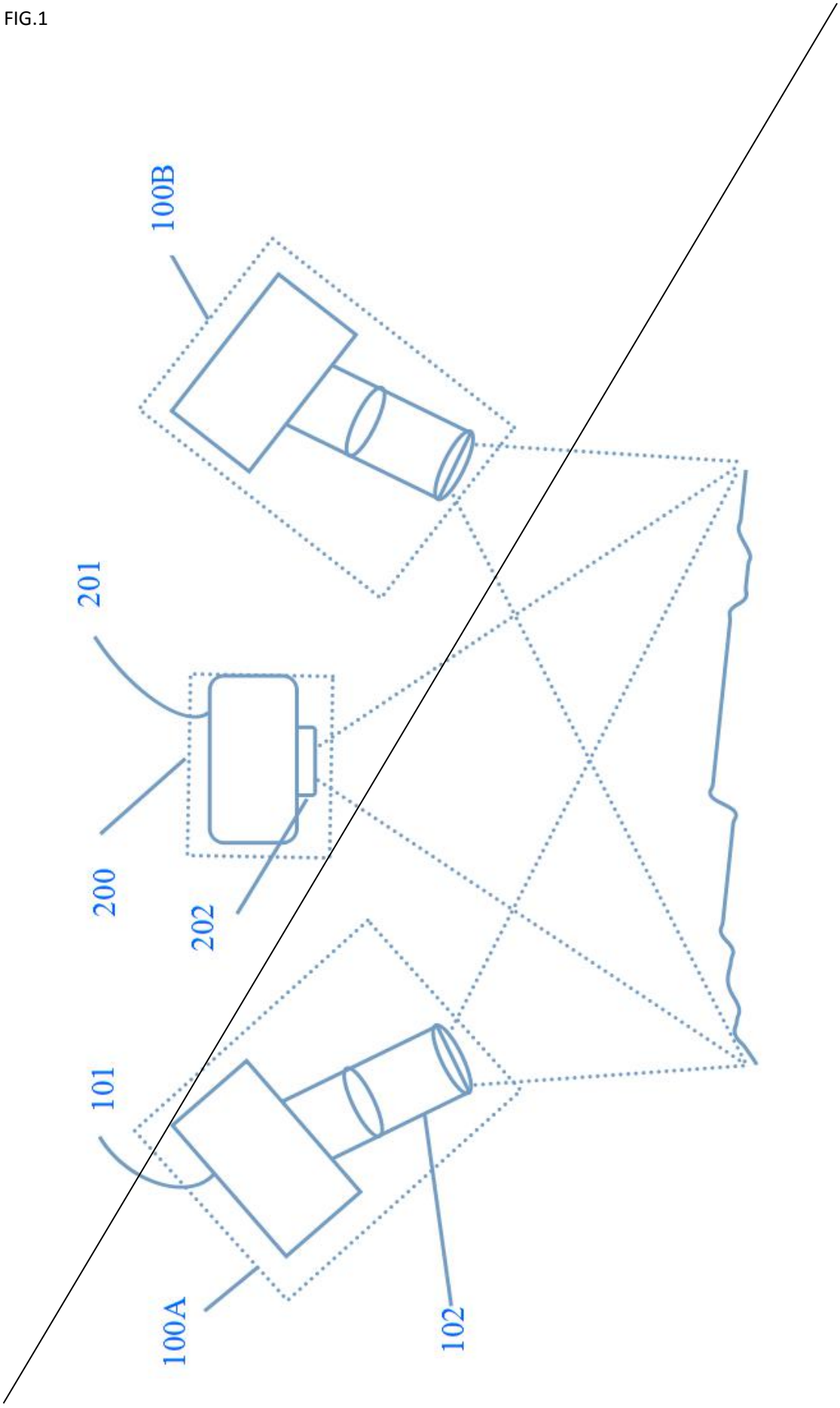


FIG.2A

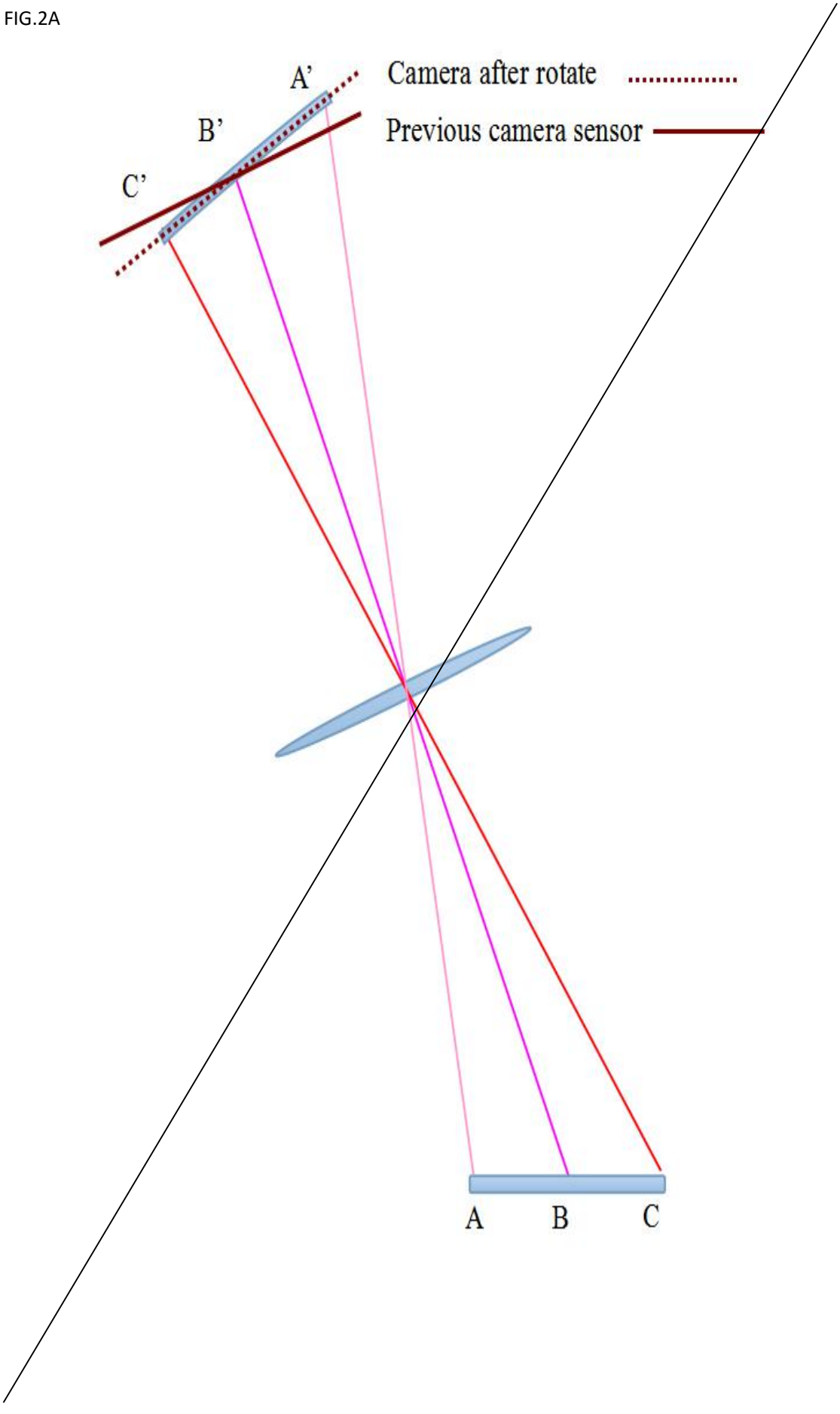


FIG.2B

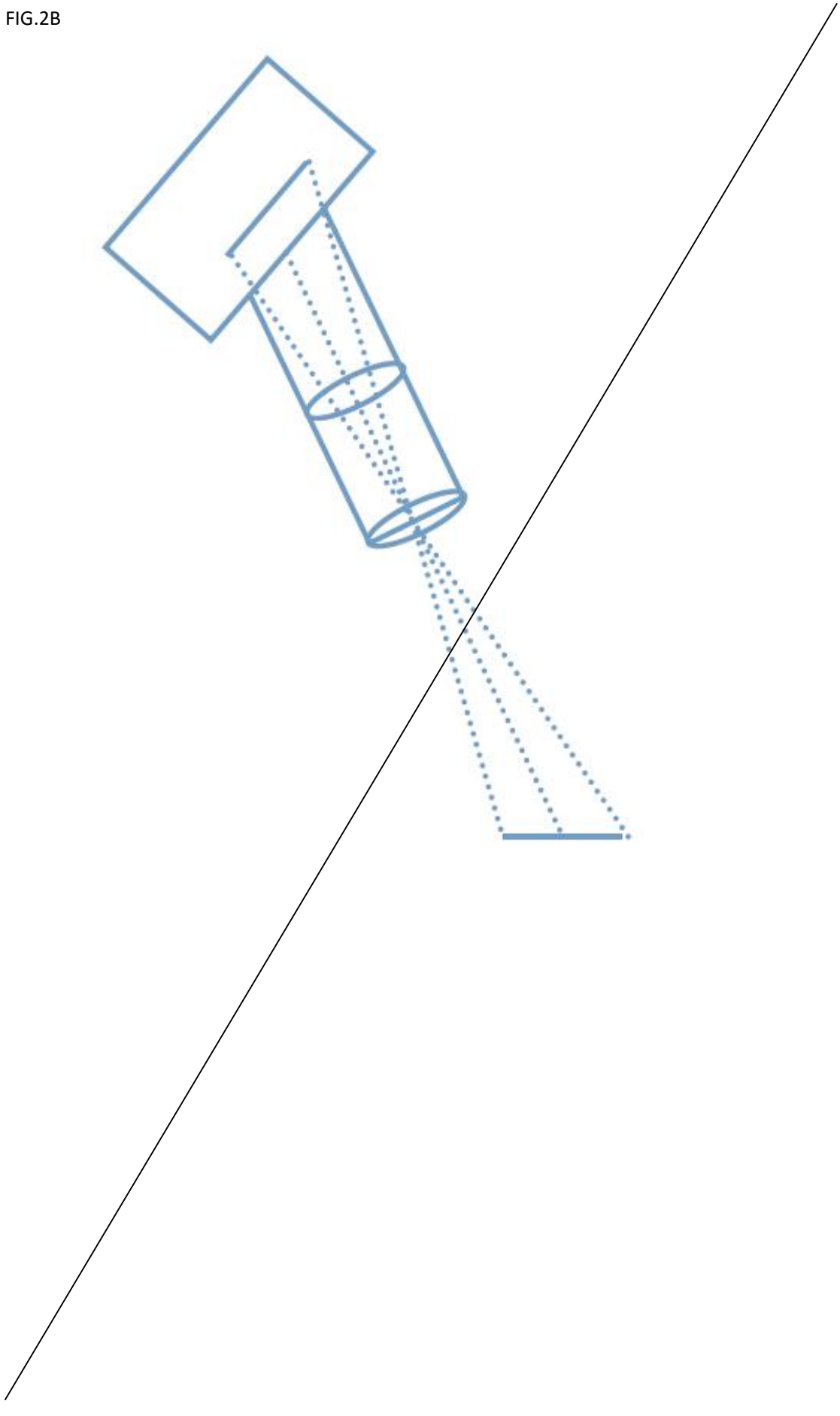


FIG.3A

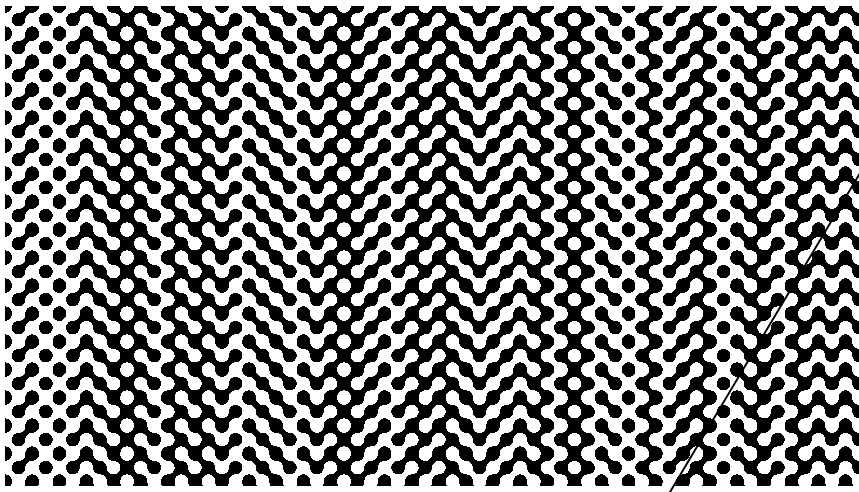


FIG.3B

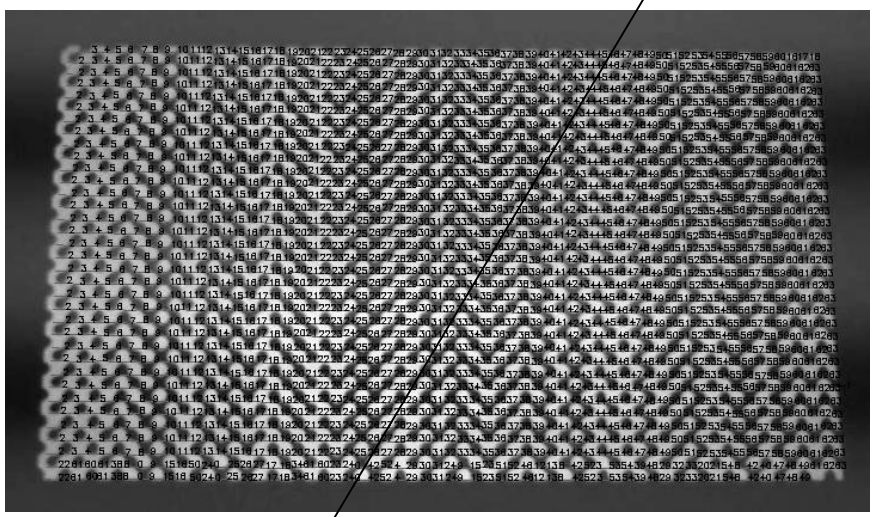


FIG.3C

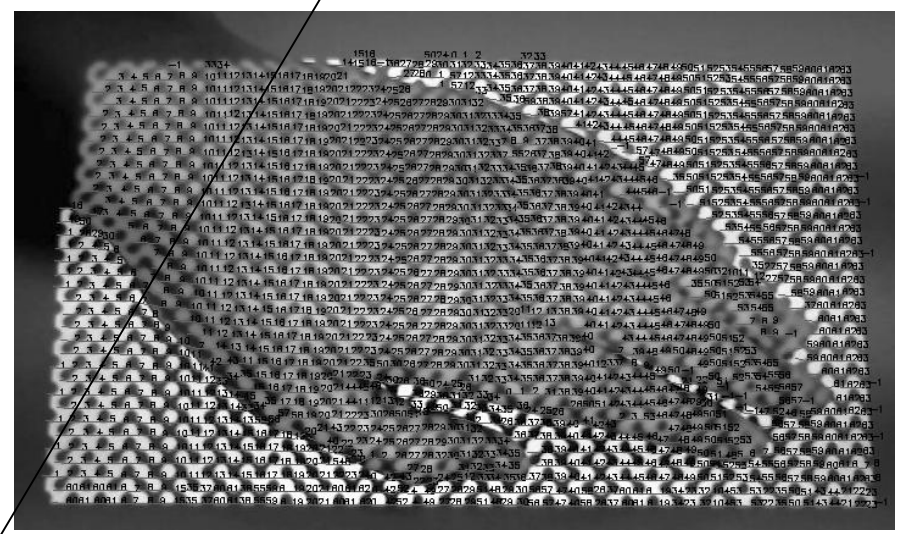


FIG.4

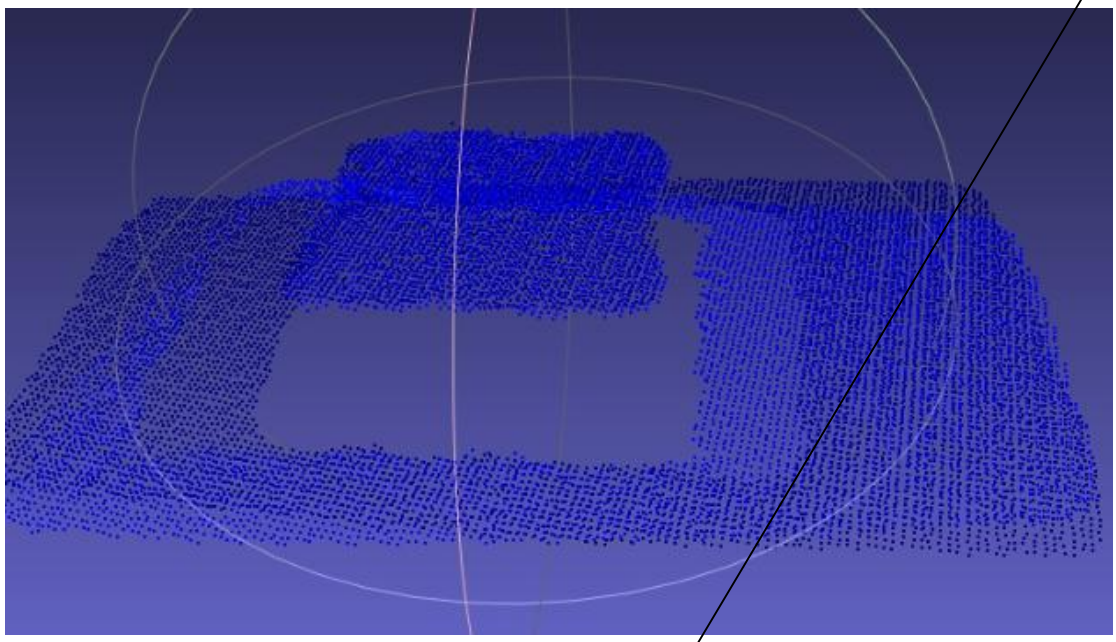


FIG.5A

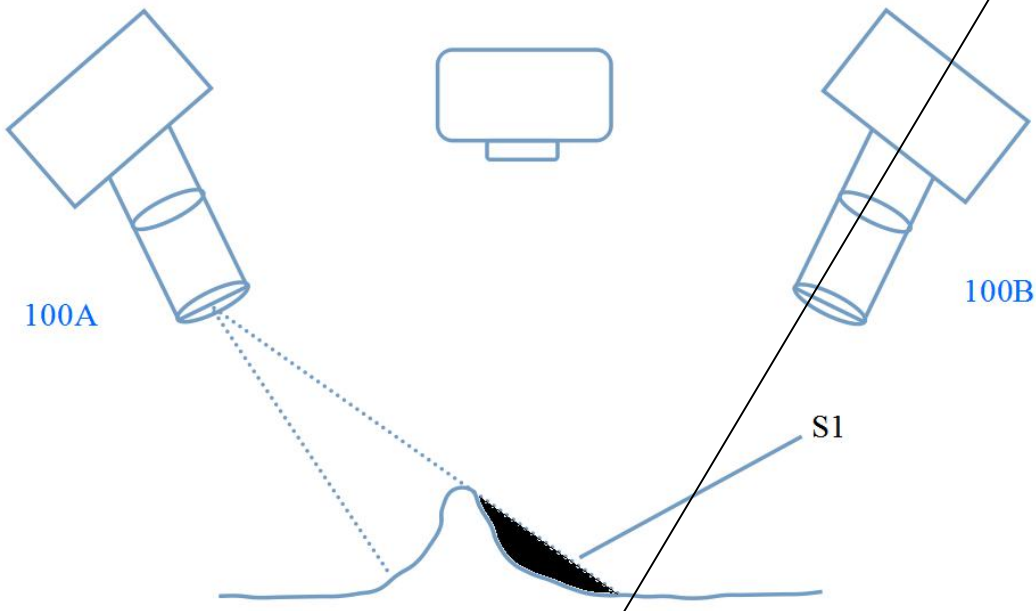


FIG.5B

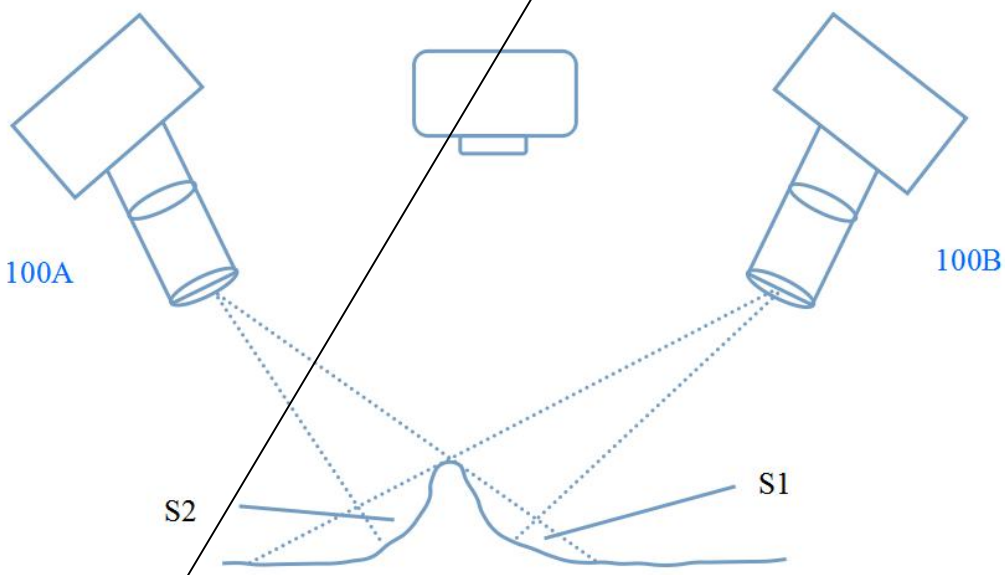


FIG.6 Look-up table

Col. Index	Cluster Index	Cluster base line		Cluster projection plane		
		c	m	a	b	c
0	0	3145	-5.5	-1.9205	-0.4835	130.1536
0	1	5509	-5.5	-3.3584	-0.7165	362.8459
0	2	7731	-5.5	-12.5152	-2.2556	1731.3676
1	0	3085	-5.5	-1.8981	-0.4802	127.3316
1	1	5642	-5.5	-3.2597	-0.6903	352.1514
1	2	7182	-5.5	-10.1633	-1.8370	1431.9892
2	0	3025	-5.5	-1.8876	-0.4796	123.9440
2	1	5408	-5.5	-3.2119	-0.6883	343.9693
2	2	7146	-5.5	-9.4902	-1.7397	1334.8076
...	...	...	...	...	...	...

FIG.7 Matching stereo pair with code pattern

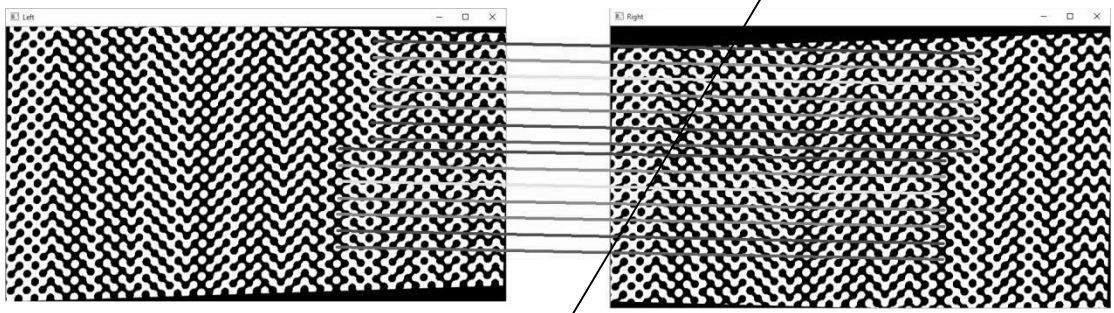


FIG.8A

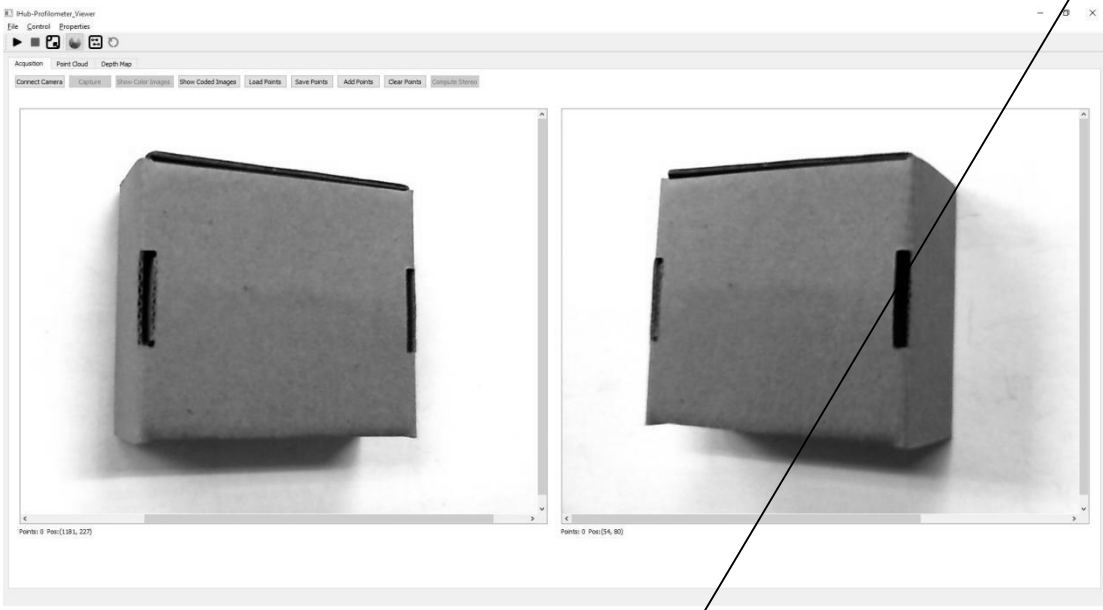

IHub-Profilometer_Viewer
File Control Properties
Acquisition Point Cloud Depth Map
Connect Camera Capture Show Color Images Show Coded Images Load Points Save Points Add Points Clear Points Compute Stereo
Points: 0 Pos:(1181, 227)
Points: 0 Pos:(54, 80)

FIG.8B

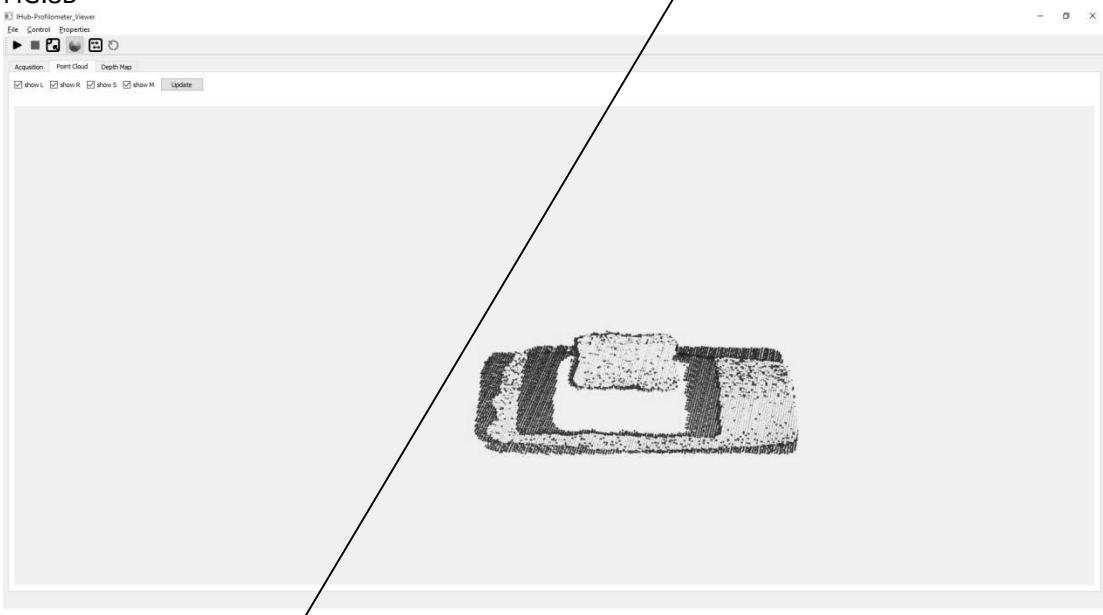
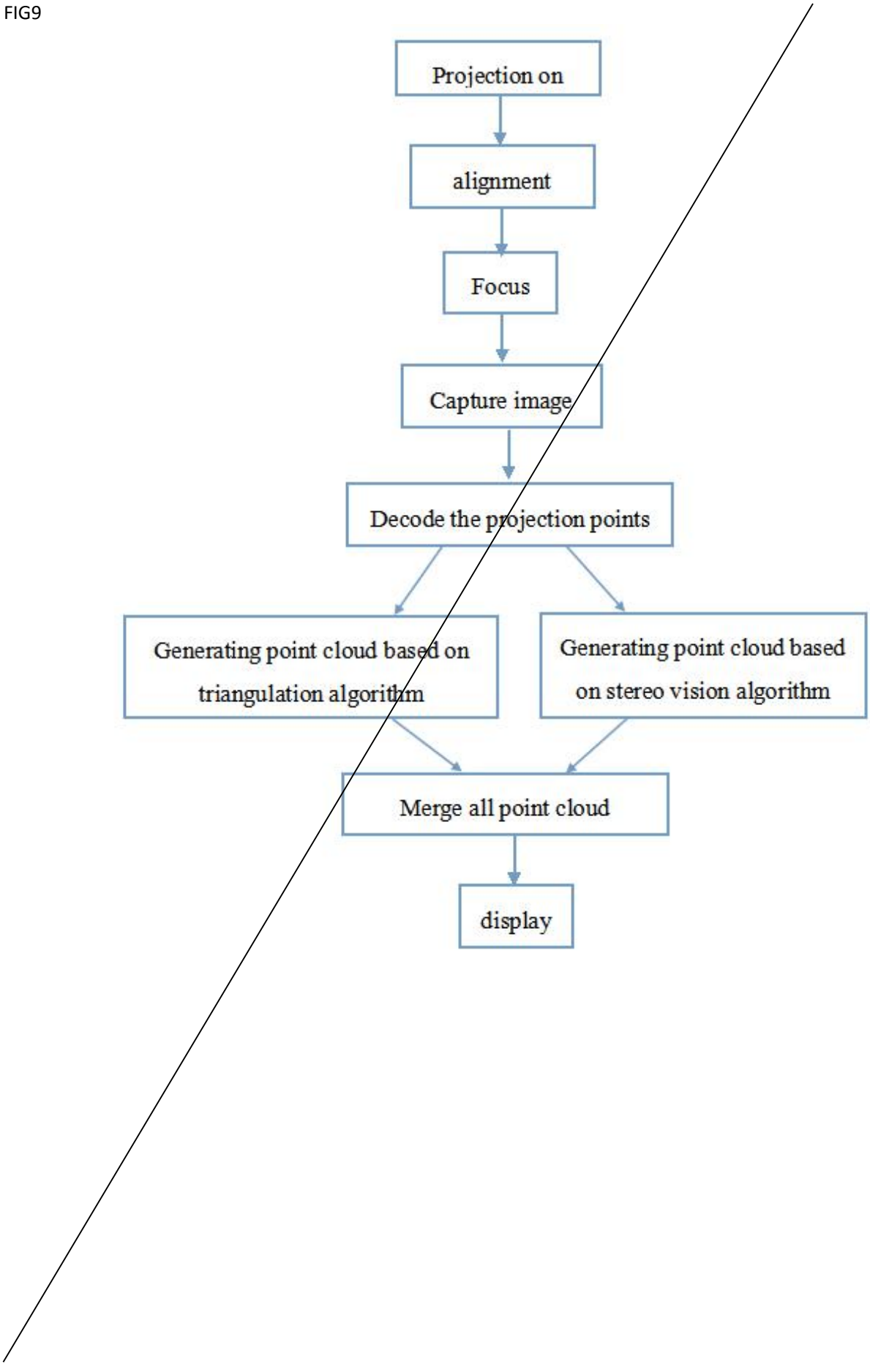

IHub-Profilometer_Viewer
File Control Properties
Acquisition Point Cloud Depth Map
show L show R show S show M Update

FIG9


Projection on
alignment
Focus
Capture image
Decode the projection points
Generating point cloud based on triangulation algorithm
Generating point cloud based on stereo vision algorithm
Merge all point cloud
display

ABSTRACT OF THE DISCLOSURE

This invention provides a 3D imaging device, a 3D imaging method and a 3D measurement program. The device works based on structure light and stereo vision technology. This device includes two light receiving units (cameras) and one light projecting unit (projector). The projector projects a coded pattern on the object surface, while the two image sensors capture the intensity from the measuring area. The two image sensors have a fixed angle with the projector. A relative distance is set between the image sensor and the object to be measured.

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[0003] FIG. 2B is the layout of the camera according to the above preferred embodiment of the present invention following Scheimpflug principle.

[0004] FIG. 3A is an exemplary picture showing a coded pattern taken by the camera 101 when the measuring surface is flat, wherein the code is well-proportioned display on the surface.

[0005] FIG. 3B shows the pattern and the code of FIG. 3A.

[0006] FIG. 3C is an exemplary picture showing an image taken by the camera 101 when there is an irregular objects laying on the measuring area, wherein the code will move according to the trigonometry principle, so the software can detect the Z height of each code point.

[0007] FIG.4 is a display of 3D cloud after decoding the image came from the camera 101 according to the above preferred embodiment of the present invention, wherein each coded point has a height and XY position, so that these points can be displayed in a 3D manner.

[0008] FIG. 5A shows a limitation when there is only one camera being used, wherein the dark area cannot be detected.

[0009] FIG. 5B shows the advantage of using dual camera, wherein the second camera will supplement the dark area of the first camera.

[0010] FIG. 6 is an exemplary picture showing a look-up table for decoding according to the above preferred embodiment of the present invention, wherein the software can get the Z height according to the code position and position shift

[0011] FIG. 7 is an exemplary picture showing how a coded pattern help stereo imaging method to find corresponding point according to the above preferred embodiment of the present invention.

[0012] FIG. 8A is an exemplary picture showing a software UI for the acquisition page according to a preferred embodiment of the present invention.

[0013] Fig. 8B is an exemplary picture showing a point cloud page according to the above preferred embodiment of the present invention.

[0014] FIG. 9 is a work-flow of the 3D imaging software according to the above preferred embodiment of the present invention.

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and applications without departing from the spirit and scope of the present invention.

[0016] With the aids of the Figures shown below, the content of techniques, features, and embodiments of the present invention is herein described, so as for the examiners to further understand the present invention.

[0017] Fig.1 illustrates the optical setup of the 3D imaging system according to a preferred embodiment of the present invention, wherein a light projecting unit 200 is used to project a coded image shown in Fig. 3A, and two light receiving units 100A and 100B are used to take the coded image on the measured object respectively. Two methods will be used to decoding the 3D position, wherein a method is decoding the position directly from the code shift, and the other method is stereo imaging.

[0018] To reduce the DOF requirement, the optical axis of camera 101 has an angle with the optical axis of lens 102 according to the Scheimpflug principle shown in Fig.2. The rotation angle lies on the angle of lens 102 with the measuring plane. The camera plane is located at the most ideal imaging plane.

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[0020] After decoding for every coded point position, the points can be displayed in 3D as the example shown in Fig. 4. Each point has x, y, z information, so as to be used for measurement and 3D reconstruction.

[0021] The trigonometry principle needs only one projection and one image sensor, but the shape of the measuring object can sometimes block the view of the camera as showing in Fig. 5A. The system according to the above preferred embodiment of the present invention uses two light receiving units in both sides as showing in Fig. 5B, so as to avoid the above drawback. Most importantly, the two light receiving units can not only be complementary to the blind spots of each other, but also provide two data clouds. Each cloud has 3D information of almost every point, so the system can obtain two position values for mostly every point, which will reduce the random error and noise.

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[0023] A feature of the present invention is that the use of two light receiving units has another purpose, which is to also apply a stereo imaging method. The two light receiving units capture the coded points at the same time. As the point is coded, the two image can easily be matched as showing in Fig. 7. Thus the system will have a third 3D cloud which can improve the 3D imaging accuracy. This method will not only capture the coded points but also detect feature points like the prominence and the edge. This will highly increase the integrity of decoding output.

[0024] The software according to the above preferred embodiment of the present invention consists several tab pages for different functions. In the acquisition page a user can see the video of the object, referring to Fig. 8A, if the cameras are connected to a computer. The user can also click an “capture” button to snap shot the images of the object at the same time and save the images to the computer. The user may open the saved images and view them in the acquisition page too. The user can input the stereo point pair by clicking the point in the left image and its corresponding point in the right image as well. The user can then click another button to request the computer to run the program to generate 3D point cloud or depth map. The generated 3D point cloud will be displayed in the point cloud page, referring to Fig. 8B, while the depth map will be displayed in depth map page.

[0025] FIG.9 shows the work-flow of the 3D imaging application according to the above preferred embodiment of the present invention. The application includes the following steps:

[0026] (a) launching the projection on the object;

[0027] (b) adjusting the fixture of the sample for interested area;

[0028] (c) focusing to the top surface of the object;

[0029] (d) capturing the images;

[0030] (e) decoding the images;

[0031] (f) generating point clouds based on triangulation algorithm and stereo vision algorithm;

[0032] (g) merging the point clouds; and

[0033] (h) outputting the result.

[0034] The step (a) is to have an applicable projection be projected on the object that is to be measured, so as to be referred to for measuring the range and other information of the object based on the images taken later. The step (b) is to adjust the fixture of the sample so as to find interested area and make sure these areas are rightly within the scope of measuring. The step (c) is to focus the cameras to the top surface of the object as it is fixed. The step (d) is to capture the images with the cameras. The step (e) is to decode the images taken in the step (d). The step (f) is to use the decoded information to respectively generate point clouds based on triangulation algorithm and stereo vision algorithm. Then the step (g) merges both of these point clouds to obtain a more accurate point cloud and 3D measurement. Lastly, the step (h) is applied to outputting the result from the step (g) by displaying on a monitor of a connected device or other ways, such as sending out an internet message or launching a 3D printing accordingly.

[0035] Specifically, for the perspective of a user, he or she may simply click a "start" icon from the step (d) in the above mentioned software according to the above preferred embodiment of the present invention, so as to have the software automatically conduct the rest of steps to measure and decode according to the images, merge and output 3 points clouds, and display the result with one 3D image.

[0036] The present invention also provides a 3D surface measuring method comprising the steps of:

[0037] (i) irradiating an object to be measured with coded light pattern with the light projecting unit;

[0038] (ii) imaging the object with two light receiving units;

[0039] (iii) displaying the captured images of the object;

[0040] (iv) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

[0041] (v) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

[0042] (vi) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

[0043] (vii) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object; and

[0044] (viii) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

[0045] Besides, the present invention provided a 3D surface measuring non-transitory program adapted for being executed by a processing device, comprising the processing of:

[0046] (I) irradiating an object to be measured with a coded light pattern with the light projecting unit;

[0047] (II) imaging the object with two light receiving units;

[0048] (III) displaying the captured images of the object;

[0049] (IV) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

[0050] (V) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

[0051] (VI) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

[0052] (VII) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object;

[0053] (VIII) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

[0054] One skilled in the art will understand that the embodiment of the present invention as shown in the drawings and described above is exemplary only and not intended to be limiting.

[0055] It will thus be seen that the objects of the present invention have been fully and effectively accomplished. The embodiments have been shown and described for the purposes of illustrating the functional and structural principles of the present invention and is subject to change without departure from such principles. Therefore, this invention includes all modifications encompassed within the spirit and scope of the following claims.

WHAT IS CLAIMED IS:

1. A 3D surface measuring device comprising: two light receiving units and one light projecting unit.

2. The 3D surface measuring device, according to claim 1, wherein said light receiving units are tilted according to Scheimpflug principle.

3. The 3D surface measuring device, according to claim 1, wherein said light projecting unit projects a coded pattern onto the surface of an object to be measured.

4. The 3D surface measuring device, according to claim 1, comprising more than two said light receiving units according to the measurement field of view and the accuracy requirement.

5. The 3D surface measuring device, according to claim 1, wherein said light projecting unit is selected from a group consisting of digital light processing projector, laser projector, and mask projector, wherein said projector connects to a piezoelectric device to conduct translational motion, so as to move the projection image.

6. The 3D surface measuring device, according to any of the claims 1-5, applying stereo imaging technology to improve the device performance, provide additional point cloud, and detect unwanted feature points of prominences and edges.

7. A 3D surface measuring method comprising the steps of:

(i) irradiating an object to be measured with coded light pattern with the light projecting unit;

(ii) imaging the object with two light receiving units;

(iii) displaying the captured images of the object;

(iv) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

(v) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

(vi) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

(vii) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object; and

(viii) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

8. A 3D surface measuring non-transitory program adapted for being executed by a processing device, comprising the processing of:

(I) irradiating an object to be measured with a coded light pattern with the light projecting unit;

(II) imaging the object with two light receiving units;

(III) displaying the captured images of the object;

(IV) decoding the code of the projection patterns imaged by the two light receiving units to identify nodes and features of the pattern;

(V) generating point clouds indicating the shapes of the object based on structural light triangulation algorithm with the device calibration data;

(VI) generating point cloud indicating shapes of the object based on a stereo vision algorithm with the camera calibration data;

(VII) merging all the point clouds to generate a depth map or a final 3D point cloud indicating the shape and surface of the object;

(VIII) outputting the depth map or the final 3D point cloud indicating the shape and surface of the object.

9. A 3D surface measuring method comprising the steps of:

(a) launching the projection on the object;

(b) adjusting the fixture of the sample for interested area;

(c) focusing to the top surface of the object;

(d) capturing the images;

(e) decoding the images;

(f) generating point clouds based on triangulation algorithm and stereo vision algorithm;

(g) merging the point clouds; and

(h) outputting the result.