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3D SHAPES MEASUREMENT SYSTEM USING AN OPTICAL MODULATOR

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Abstract: We have continued research on 3D shapes measurement system using spatial modulator. The advantages of this system are non-contact, non-invasive, and short time measurement. We proposed a method using differentiation to expand the measurable area and improve the accuracy of measurement. Additionally, We proposed to eliminate the influence of marking on target object surface. It was a very practical and effective method.
Keywords: Three-dimensional (3D) shapes, Spatial modulator, CCD-camera

1. PUEPOSE

Our system obtains coordinates in 3D space by projecting electronically controlled striped patterns of light onto the target object. The reflection of the light patterns from the target object are received by a CCD camera. In this study, we aimed to reduce changes in the stripe pattern's signal intensity caused by reflection of the target object itself, and expand the measurable area and improve the accuracy of measurement. Additionally, we proposed to eliminate the influence of marking on target object surface.

2. MEASUREMENT PRINCIPLE

The principle behind the 3D shapes measurement system is as follows. The physical spatial coordinate axes are marked X, Y and Z, while the observed 2D axes are marked x and y. A stripe array pattern is projected onto the target object from the light source. The projected stripe array pattern, seen from a different direction from the light source, is deformed according to the surface shape of the object. This deformed pattern is measured, and converted from 2D to 3D coordinates.
(Figure1, Equation1)

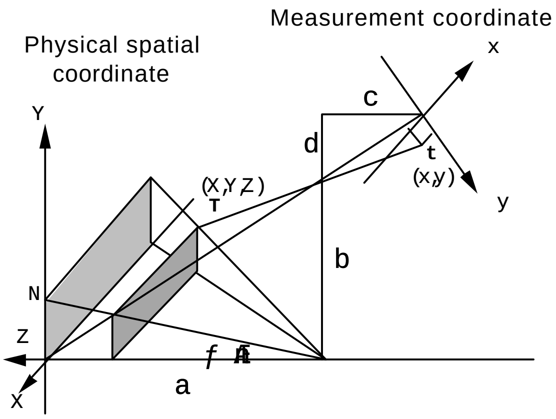

Figure 1.

$$X = -b\sqrt{a^2+b^2}\,x / H$$
$$Y = (mab\sqrt{a^2+b^2} - b^2 y)\tan qn / H$$
$$Z = ((-ma^2\sqrt{a^2+b^2} - aby)\tan qn - a^2 y - b^2 y) / H$$
$$H = (ma\sqrt{a^2+b^2} - by)\tan qn + mb\sqrt{a^2+b^2} + ay$$
$$m = c/a = d/b$$

Equation 1.

3. 3D MEASUREMENT SYSTEM

The structure of the system is shown in Figure 2. In this system we use a liquid crystal projector to form stripe array patterns. The liquid-crystal projector allows instantaneous and precise stripe pattern control without any mechanical operation. The stripe pattern projected onto the target object is received by a CCD camera placed in a different position from the light source. The deformed stripe pattern according to the form of the target object is first converted into two coordinate values, then into a thin line, sampled and finally converted into 3D coordinates (Figure 3).

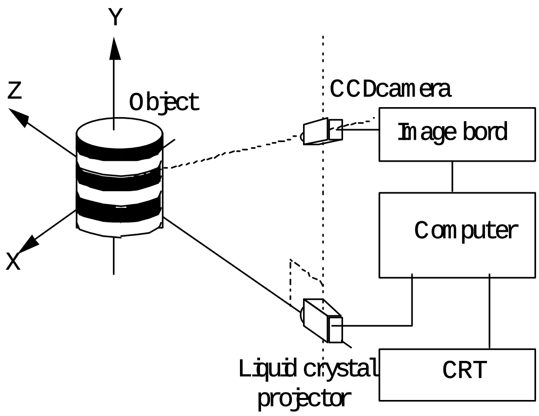

Figure 2.

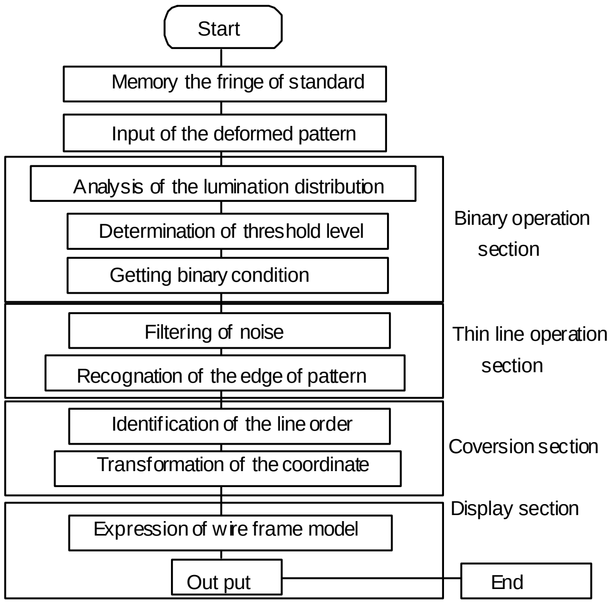

Figure 3.

4. EXPANDING THE MEASUREBLE AREA AND IMPROVE THE ACCURACY OF MEASUREMENT

4.1 METHOD

We performed instantaneous projections of one with stripe patterns, and one without. Then, we differentiated by computer. The differentiated data was converted into two coordinate values, then into a thin line, and finally 3D coordinates.

4.2 RESULTS

Figure 4 shows the target object. Figure 5(a) and 5(b) show the binary and thin lined images using conventional method. Figure 6(a) and 6(b) show the binary and thin lined images using newly method. By using the newly method, the measured area were expanded and the accuracy of measurement was improved.

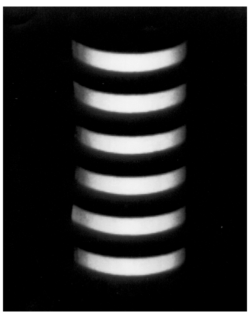

Figure 4.

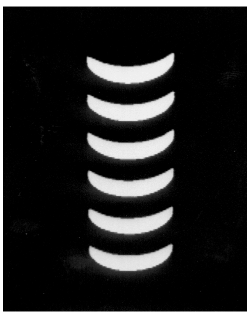

Figure 5. (a)

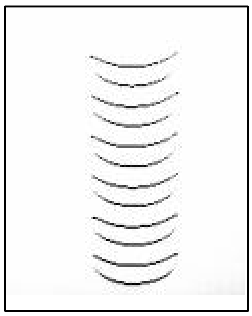

Figure 5. (b)

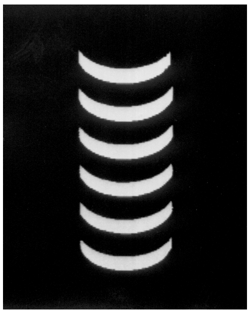

Figure 6. (a)

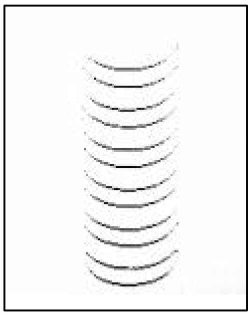

Figure 6. (b)

The results of the 3D measurement are shown in Figures 7 and 8. The results show the X-Y plane obtained from data for a chosen stripe. Since the target object was a cylinder, the data should show a portion of the locus of the circumference of a circle.

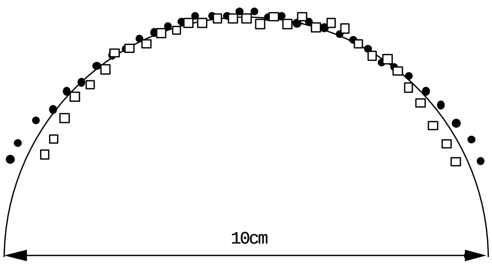

Figure 7.

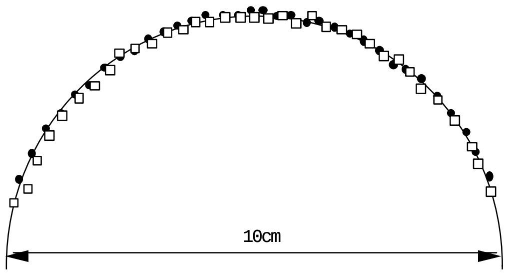

Figure 8.

5. ELIMINATION OF MARKING ON THE TARGET OBJECT SURFACE

We succeeded in expanding the measurable area and improving measurement precision by differentiating the images taken under two conditions; with and without stripe patterns. We tried to eliminate markings on the surface of the target object by applying this technique. In 3D optical shape identification, colors and patterns on the target object surface can be obstructive. However, we can eliminate the effects of markings on the target object surface by using the image differentiation technique reported in the preceding section.

5.1 METHOD

The experimental method used was fundamentally the same as that described in the earlier section. However, the signal intensity of the stripe patterns for each target object must be kept the same in order to conduct image differentiation. In this case, we used as our target object a cylindrical styrene foam container with markings on the surface. We obtained one image from a stripe pattern projected onto the target object, and another image without the stripe pattern: uniform light was projected onto the target object. After differentiating these two images, we conducted conversion into dual coordinate values, thin line, and 3D coordinates.

5.2 RESULTS

Figure 9 shows the target object with marking on the surface. Figure 10 shows the image obtained when the stripe pattern was projected. Figure 11 shows the result of binary operation using image shown in Figure 10. The markings on the target object surface appeared, preventing accurate 3D shapes identification. Figure 12 shows the differentiated image between images shown in Figures 9 and 10, and performed binary operation. The markings on the target object surface have thus been eliminated.

Figure 9.

Figure 10.

Figure 11.

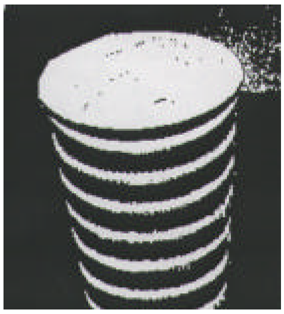

Figure 12.

6. CONCLUSION

Differentiation of images with and without stripe pattern projections has led to an expanded measurable area of the target object, and improved measurement precision, as well as the elimination of the effects of markings on the target object surface. Colors and markings on the surface of target objects have been great obstacles in performing 3D shape identification. The development of our image differentiation technique provides an easy solution to this problem.

Although this method requires the projection and image acquisition procedure to be done twice, computer control can shorten this time without difficulty. We believe that this technique will become widely used in the future.

REFERENCE

Katsumi Tsujioka, H. Ito, H Fnahashi, S. Higa, N. Hayashi, J. Yamada, K. Hatano and Y. Uchida, Three-Dimensional Shapes Measurement using Gtaring Patterns from an Optical Spatial Modulator, Proceeding of 9th Korea Automatic Control Conference, International Sessions, (1994) pp. 561-565.

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