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A High-speed 3D Image Measurement Method

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Abstract: **The intensity modulation projection technique has been in great anticipation of practicability with the popularization of digital camera and projector recently with reason that it may get much more information with single projection pattern through measurement and calculate the high sensitive 3D information. But the technique is premised on the situation that it must get observation pattern image with essential number of stripe and intensity distribution, that is to say, the ideal observation pattern image so as to secure the sensitivity and accuracy of measurement. So, as for the target object without specification on the surface reflectance and distribution of surface color, the measurement would encounter several problems such as deficiency of the volume of information on the observation pattern, uncertainty of the target measurement sensitivity as well as the trouble of measurement manipulation. In order to solve the problems presented above. We propose an image analysis method of intensity correction with synthesis image technique in order to extract the stripes precisely when measuring the 3D shape of an object by using single projection pattern. By using this analysis method, if the surface reflection of the target is simple, 3D shape measurement is realized using only one observation image.**

Keywords: **3D Shape Measurement, Optimal, Intensity Modulation, Pattern Projection, Image Synthesis.**

I. INTRODUCTION

Three-dimensional (3D) shape measurement has different applications in engineering fields, such as inspection of product quality, face recognition, body surface evaluation, and surgery simulation and navigation in biomedical engineering[1].

At present, popular 3D shape measurement techniques include stereo vision, structured light, moiré method, and the other methods. Depending on the light source and the receiving style, many techniques have been proposed, active systems and passive systems. The stereo vision is based on imaging the scene from two or more points of view and then finding correspondences between the different images in order to triangulate the 3D position. Triangulation is possible if cameras are previously calibrated. The structured light technique generates a full pattern to cover the object so that the surface can be captured as a whole field recording. Therefore, the encoding of the structured pattern becomes important because it determines the local features of the recorded images to be identified in spatial recognition and height evaluation.

When we measure a color object, the color distribution of the object often influences the code word of project pattern; here we use a monochrome projection pattern to avoid the influence from color. In this method, we only do analysis on the intensity of the observation image, so the combination of monochrome projection and monochrome analysis do not take object color into consideration. Here we use optimal intensity modulation pattern, which is made by a special algorithm. This kind of pattern is easier to do the stripe extraction just because the adjacent stripes have a good maximum intensity difference, which makes the stripe easily to be distinguished[2-3].

In this paper, we propose an analysis method based on the optimal intensity modulation pattern projection technique, in which a structured monochrome projection pattern is projected and a color image of the observation pattern is captured. The paper focuses on the optimal analysis of optimal intensity modulation projection technique by using single projection pattern and the contradistinction against the conventional methods in stripe analysis. The intensity distribution stripes offer an identifiable pattern so that the whole surface pattern image of the object can be obtained to easily analyze surface depth information by triangulation. Not only can we get better detection accuracy and faster computation speed through optimizing the stripe intensity distribution, but also can get better stripe order detection by modulating the intensity differences between adjacent stripes[4-5].

II. ALGORITHM

Figure 1 was a composition of typical 3D shape measurement system. The projection pattern been

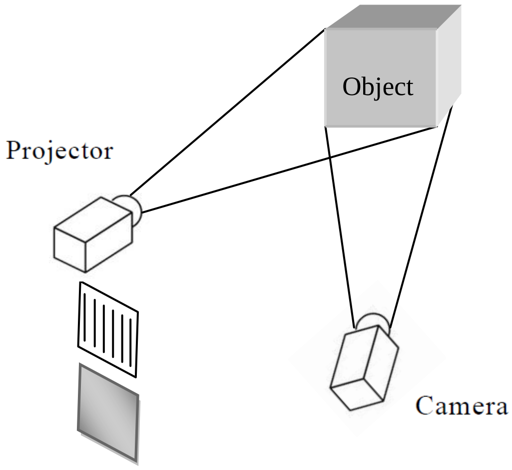

Fig.1. 3D shape measurement of pattern projection system

output by the computer was projected to the measurement object from the projector, camera was used to take a picture of the projected pattern reflected to the measurement object as an observation pattern image, finally, the information stored in the camera was input to the computer. Next, the directions of the stripes of projection pattern were detected from the observation pattern image which had been input, and then 3D shape of the object was restored based on the principle of the triangulation. The following contained processing of each step was stated simply[4].

Step1: Projecting optimal intensity modulation pattern to measurement object.

Step2: Taking a picture of the image and using it as the initial observation pattern image.

Step3 ： Doing color analysis of the initial observation image and synthesizing the image for the measurement based on the color channel for the measurement. The color channel that reflection intensity value was stronger than the others was extracted every pixel from input image and used it as the channel for the measurement. The influence caused by other color components and the surface reflectance in the same part of the measurement object were reduced by synthesizing single channel image for calculation with a channel for the measurement of each pixel.

Step4: Extracting measurement object from the image for measurement and deleting the noise with threshold extraction method.

Step5: Confirming the influence of surface reflectance. If there were no influence, Step 6 should be omitted and jumped to step 7 directly.

Step6: Correcting the influence of the surface reflectance of the measurement object from the image for the measurement with the object of detecting stripes address in high accuracy and sharpening stripes pattern for the measurement. In the following Chapter 3, we described the technique and principle.

Step7：Extracting slit pattern address in the light of a linear relation of each stripes intensity value from the corrected image for measurement because the intensity value of each stripes pattern was decided by majority according to the intensity value of each pixel of each stripes pattern.

Step8：Calculating the 3D space world coordinates based on the detected stripes address. The calculation of three dimension shape by using the principle of the triangulation was omitted in this thesis.

III. PRINCIPLE AND METHOD

1. Problem of reflectivity reduction

About the optimal intensity modulation pattern projection measurement, it was ideal that the relation between the intensity of the reflection pattern stripes obtained from the input image and a pattern stripes degree were a one-to-one correspondence in order to obtain three dimension shapes with accuracy. However, the measurement object was multiple color distribution, and it was difficult to obtain such an ideal relation when it had reflectivity taken with a versatile digital camera. Generally, the gray projection pattern was projected to the measurement object with a variety of color distribution, information obtained from the reflection pattern image was only brightness, coordinates, and color information on the measurement object decreased and the measurement range confused became narrow[6].

2. Past method of intensity correction

For the projected pattern intensity $P(x, y)$, if pixel intensity $I(i, j)$ in the image was always (1), the correction method of traditional reflectivity should be ideal.

$$P(x, y) : I(i, j) = 1:1 \qquad (1)$$

Actually, Surface reflection element $O(x, y)$ of the object can be actually contained, and intensity of each pixel in the reflection pattern image that hit the object be shown as follows.

$$I_l(i,j) = P_n(x,y) \times O(x,y) \qquad (2)$$

At this time, because the surface reflection element had its influences in (2), stripes degree n of $P_n(x,y)$ cannot be detected. Then, we projected projection pattern with uniform intensity $P_f(x,y)$ to the same measurement scene, the relation of (3) was obtained.

$$I_f(i,j) = P_f(x,y) \times O(x,y) \qquad (3)$$

The following relation was obtained from (2) and (3).

$$\frac{I_l(i,j)}{I_f(i,j)} = \frac{P_n(x,y)}{P_f(x,y)} \qquad (4)$$

That is to say, the image for the calculation with the projection light stripes intensity distribution and linear correspondence was obtained by the dividing calculation correction. With correction method, steady stripes pattern for measurement could be obtained, but confronting the fact, which meant its difficulty to deal with the moving object, furthermore, it is necessary to use two pieces of observation image, which made the measurement cost time[7].

3. Propose method of intensity correction

Previous method can give us a good result when measuring a stationary object. Typically, this method takes time to send two frames of projection pattern when measuring. In fact, we do not need high precision of the full-light observation image which means not very necessary to do the full-light image capturing. If we can analyze the distribution through some processing algorithm, the original image after gray scale may be not necessary.

In order to realize 3D shape measurement using one image, we propose an optimal image analysis method. Intensity information of no-pattern area is used to recover intensity information pattern area. Color changes of object surface have little effect on the change of reflectivity. So we set a specific filter to do recovery of pattern pixel in this specific domain. We try to use the neighbor pixel intensity of the no-pattern area to fill in the pixel of pattern area, and then let the filter move to the next pixel to do the same work of the correction processing. Under this way, we could obtain the random pixel intensity distribution, this kind of information transference still carry over the no-pattern pixel intensity approximately. We can obtain a synthesis full-light image by using this method, in which there is no pattern area. We use this synthesis image to do division calculation, and then to avoid the effect of reflectivity of object surface color. At last, pattern image used for measurement which is in linear relation is obtained.

IV. OUTCOME OF AN EXPERIMENT

The experiment was done in the spaciousness environment where the lighting was erased. The experiment system was composed of the liquid crystal projector, the CCD color camera, and the computer, the stripe number of the optimal intensity modulation projection pattern was set to 20.

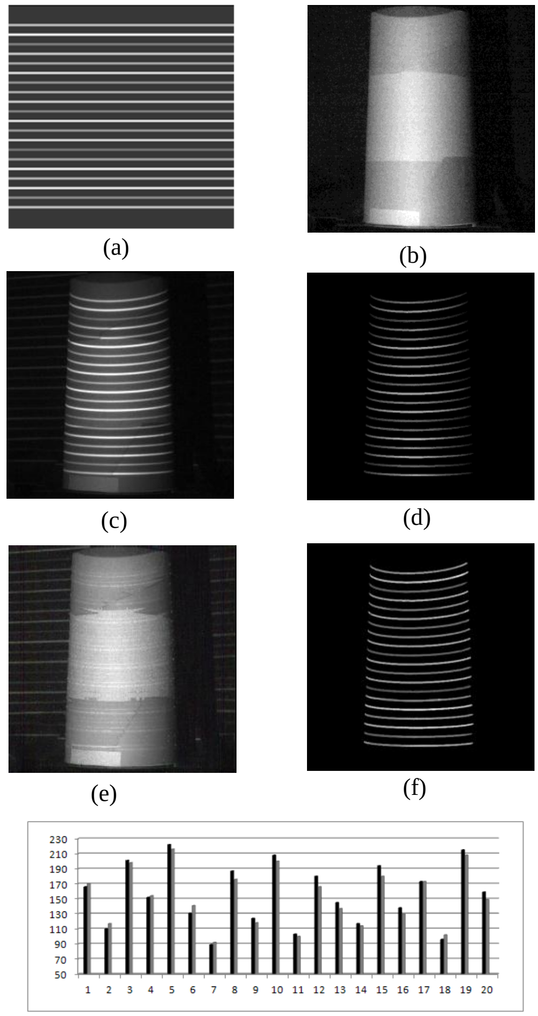

Fig.2 Experiment result: (a) Optimal intensity modulation projection pattern. (b) Column object.
(c) Observation pattern image. (d) Extracted pattern image. (e) Synthesis image. (f) Corrected pattern image.
(g) Intensity distribution image for comparison.

First of all, 20 stripes (Figure 2(a)) optimal intensity modulation patterns were projected to the column (Figure 2(b)), the reflected pattern, as an observation pattern image (Figure 2(c)), was taken a photo by camera. And, the observed pattern was extracted, which formed extracted pattern image (Figure 2(d)). Next, the synthesis image (Figure 2(e)) by the technique of propose was generated, Pattern intensity was corrected by the dividing calculation with Figure 2(d) and Figure 2(e), which formed the corrected pattern image (Figure 2(f)). Figure 2(g) is the comparison of the intensity distribution of Figure 2(a) and Figure 2(f), just shown here, it can be seen that the intensity distribution of the corrected image is almost similar with the one of projection pattern image, our method is successfully proved to be done in this kind of correction processing.

V. CONCLUSION

The paper presents a technique of 3D shape measurement by using single projection pattern to do optimal analysis based on convolution theory. The optimal intensity modulation projection pattern is chosen to encode the surface area of the object; and uniform intensity projection pattern formed by program is used to reduce the impact of the colors in stripe region. This method is applied to revise the color distribution of projection pattern stripes by using the background information in 3D projection pattern measurement technique.

The future task is to measure object surface which has complicated texture, and verify the robustness of this technique.

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