Stripes Extraction Technique of Projection Pattern for 3D Shape Measurement

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Abstract: **3D image measurement based on pattern light projection can be roughly classified into two groups, binarization type and non-binarization type, from projection pattern intensity and color distribution characteristic. Binarization type is a method of using binarizationalized projection and image, but there are some difficult problems such as the necessity to do the multi-projection so as to detect information of the projection patterns, much time spent on measurement manipulation as well as the correspondence to the move objects. Non-binarization type is a method of using the non-binarizationalized projection pattern, monochrome image or color image. The 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 through binarizationalized measurement and calculate the high sensitivity 3D information. But the technique is premised on the situation that it must get reflex pattern image with essential number of slit 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 reflex projection patterns, uncertainty of the target measurement sensitivity as well as the troublesome of measurement manipulation. In order to solve the problems presented above, I propose Fast Fourier transform (FFT) technique on one initial observation image in my study. Furthermore, I strove for 3D image detection by using one initial observation image by single pattern light projection through merging the technique of monochrome projection-color analysis (MPCA) with the optimal intensity modulated projection (OIMP) together, which resulted in the high speed and high accuracy of 3D image observation.**

Keywords: **Pattern Projection, Frequency Domain, Monochrome-projection, Color-analysis.**

I. INTRODUCTION

Figure 1 showed the projection pattern used a measurement technique, saying, intensity modulation pattern projection measurement technique. Intensity modulation pattern projection technique was that adding the intensity modulation which had been made correspondence between stripes location information and the intensity information to projection patterns and doing 3D measurement by using their correspondence between the stripes intensity value of the projection pattern and the stripes intensity value of the observation pattern image. But taking discontinuance between stripes of the projection pattern into account, it's possible to make a steady measurement to resist noise with comparison to analogue technique such as the density inclination pattern etc. If the intensity modulation pattern with N pieces of stripes was projected and stripes address were to be detected from the observation pattern image correctly, the depth measurement sensitivity equivalent to slit optical projection as often as N times should be obtained by single measurement.

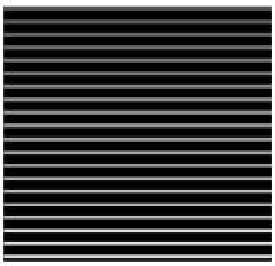

Fig.1. Intensity modulat ion pattern

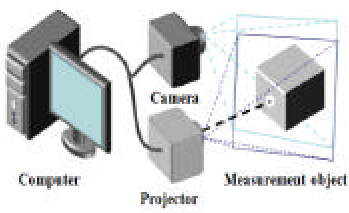

Fig.2. Pattern projection measurement svstem

The traditional intensity modulation pattern projection technique was chiefly projected to the grey intensity modulation pattern and utilized image analysis technique through grey scale input, but it has been proved to be difficult to obtain reflection pattern with necessary measurement range in the case of measuring objects with multiple color distribution. Owing to its necessity to correct slit pattern by taking more than 2 photos so as to get wide measurement image of the intensity range, the measurement was always costly and hard to deal with the moving object. In the present study, the observation pattern image with a wide and ideal stripes intensity distribution of the intensity range was automatically acquired by using the monochrome projection color analysis technology, furthermore, as to the synthesized observation pattern image, the influence of the measurement outcome due to the measurement condition, such as surface reflectance of the target object, was reduced by the Fourier transform in the frequency domain. Because of the possibility to detect stripes address by sharpening slit patterns, the problems mentioned above were solved, which would result in the reduction of the cost and improvement of the measurement accuracy.

II. ALGORITHM

Figure 2 was a composition of typical pattern projection measurement system. The projection pattern been 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.

Step1: Projecting 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. To reduce the influence on the measurement result according to the measurement condition of the surface reflectance etc. of this object, it proposed the Fourier transform technique of the image in the frequency domain in the present study. In the following Chapter 3, I 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 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 shape 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, color information on the measurement object decreased and the measurement range confused became narrow.

2. Space area correction method

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 $P_n(x, y)$ can not 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, the necessity to have two pieces of observation image made the measurement cost expensive.

3. Frequency area correction method

Rather than delete surface reflectivity from each pixel, my study aimed to obtain measureable stripes pattern in the power spectrum within the frequency area of the whole image by using single observation image.

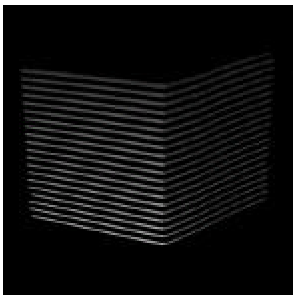

Fig.3. Synthesized measurement image

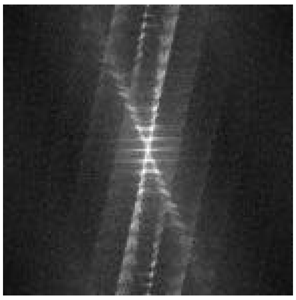

Fig.4. Power-spectrum of image for

Here, Figure 3 showed the synthesized image for measurement, while Figure 4 was power spectrum of the measurement image. According to Figure 3 and Figure 4, it was clear that a power spectrum image with a characteristic of the periodic light and shade pattern like the synthetic measurement image had the repetitive brightness edge. For instance, against the engine arranged in the vertical direction of the power spectrum image, it was composed in the horizontal direction on the original measurement image. If a strong edge existed for a power spectrum image's diagonal depending the length edge, to lean to the right, and to come, it should be comprehended to arrange stripes pattern in each edge and the direction (for left diagonal horizontal direction) in which it goes directly in an original measured imagery. But, when the patterns in all directions confused in the measurement image, the frequency image scattered everywhere, so the power spectrum was. At this time, it meant that the bright places and low frequency existed so many in the center of the power spectrum, in reverse, high patterns of the frequency existed in the far, direct component lied in the center.

The method of the present study was that extracting stripe pattern from the initial observation image, synthesizing the image for the measurement. And, stripes pattern was converted into a power spectrum image from this composited image, and then, stripe pattern was sharpened in the light of the extraction of the frequency of stripes pattern for the measurement in the power spectrum of the composite image, finally, measurement image reflectivity was corrected. The extraction method of stripes pattern was done by setting the threshold in a power spectrum image. In addition, when stripes pattern for the measurement was a curve, which made the edge of the corresponding power spectrum was not clear, the number of low frequencies was extracted by using the nether Butterworth filter another time as an auxiliary means after the power spectrum of stripes pattern was extracted from the threshold, stripes pattern was sharpened at last.

$$H(i, j) = \frac{1}{1.0 + (\sqrt{2} - 1)\, p^{\frac{1}{4}}} \qquad (5)$$

Here, $H(i, j)$ was coefficient of the filter; p was the distances from each pixel to the image center in a power spectrum image (The unit: pixel).

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, an ideal stripes number of the projection pattern was set to 20.


Fig.5. Measurement object measurement

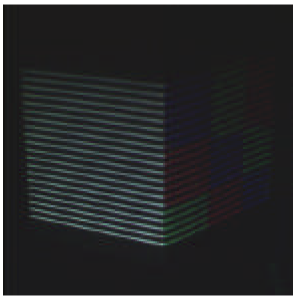
Fig.6. Initial image of observation pattern

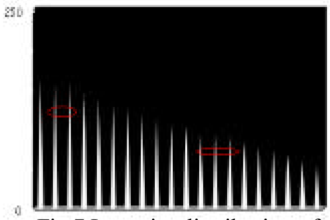

Fig.7 Intensity distribution of measurement composition

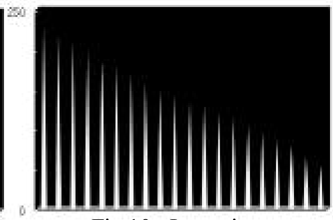

Fig.10. Intensity distribution of correcte

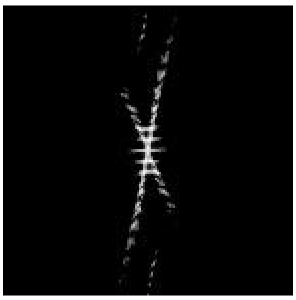
Fig.8. Extracted power-spectrum

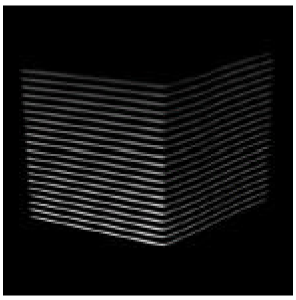
Fig.9. Corrected measurement image

Stripes pattern after the calibration of Figure 1 was projected from an algorithm above-mentioned Chapter 2 to the measurement object of Figure 5, it took a picture, and an initial image of Figure 6 was obtained. The measurement image of Figure 3 was compounded by using color analysis, because the intensity range of the measurement image which had been compounded became narrower on the one hand, the intensity distribution was not linear on the other, the accuracy of detecting stripes address was obtained. Figure 7 showed the intensity distribution of the composite image, we can find something influential came from the surface reflectance (Stripes enclosed in a red line were not linear, and the intensity range narrows down greatly, too). So as to decrease influence, we sought for the composite power spectrum image through Fourier transform (refer to Figure 4), extracted power spectrum of the stripes pattern in it, conversed to Fourier and did image correction. Figure 8 showed the image of a power spectrum of the extraction. Figure 9 showed the measurement image which had been corrected. Figure 10 showed the intensity distribution of measurement image which had been corrected. We have known that the stripes intensity distribution at this time was almost distributed in a linear target, intensity range became wider.

V. CONCLUSION

In the present study, it proposed three dimension measurement technique of the object with multiple color distribution by using Fourier transform technique from one initial observation image. According to the characteristic of the measurement system, the intensity modulation pattern calibrated was projected to the object with the multiple color distribution, and color information in the reflection pattern image filmed was analyzed, And then, the image for measurement was compounded, finally, the wide range intensity distribution stripes with projection pattern stripes degree and linear correspondence can be obtained by the intensity correction of the measurement image. Thus, it was possible to utilize effectively image information and resulted in a high efficiency and accurate measurement.

The further study of the validity concerning the technique proposed here in the case of the objects with multi-materials and its system practicability would be mentioned as the assignment in the future.

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