Face Detection and Face Authentication Based on 3D Face Image

Hiroya Kamitomo and Cunwei Lu

Fukuoka Institute of Technology, 30-1 Wajirohigashi3-chome, Higashi-ku, Fukuoka
(Tel : 81-92-606-7395)
(bd09001@bene.fit.ac.jp)

Abstract: The technique of face authentication is needed which can be used also by cases, such as make-up face or illumination change. The past technique based on 2-D color image showed low authentication rate, in the case of a photography environmental variation or makeup. We proposed a technique of face authentication based on 3-D face image. In order to solve the above problem, we used the 3D image measurement technique to acquire 3D fac e image and used 3D face image to perform face recognition. In this paper, the 3-D face image measurements are explained. First, I explained the application to the direction detection of the 3-D face. after that. Finally, I explained the application to the 3-D face authentication for security or an access control.

Keywords: *3-d shape measurement, range image, face detection, face authentication*

I. INTRODUCTION

There is a variety of measurement techniques proposed so far. First, stereo vision technique, which is a method to calculate 3-D coordinates in accordance with the principle of the triangulation by way of taking a picture of the measurement object from plural directions with camera. But it is difficult for detection automation on the curved surface and the very confined edge on account of its necessity to detect the correspondence point from two or more images. Therefore, the method called pattern light projection [1] has been prevailing in the case of requirement to measure 3-D shapes in a high sensitivity. Aiming at the measurement object, the ability of decomposition should be improved for the addition of features actively by projecting the pattern light with some features from the projector. The method of Pattern projection has been classified fully into various techniques, depending on the variety of light. The space encoding pattern projection method [1] used stripes pattern of monochrome binary added a binary code to the measurement object with increasing the pitch of light and shade in time sequencing order. In a word, n bit of binary code are allocated in each area of the measurement object by the stripes pattern projection as often as n times. However, it is beyond handling dynamic scene for the time problem and the increase of times of pattern projection so as to do a high decomposition. The density inclination pattern projection method and the color pattern projection method are used multilevel intensity-modulated projection pattern [2]. Owing to the color distribution and reflectivity on the surface of the target object, a lot of projection angle information is obtained by single filming theoretically. The pattern feature after projection has been changed, which would result in the difficulty about the detection of steady projection angle information, and finally its reliability can't be secured.

We proposed the practicable 3-D image measurement system based on optimal intensity-modulation projection technique [3]. It is used as a technique for stabilizing multilevel intensity-modulated projection pattern stripes and extracting them. Stripes detection accuracy can be improved by optimally combining the order of stripes strength of the projected pattern with the strength difference between stripes to the maximum. Thus, for the measurement object that is hard to keep motionless, like human being, it is possible to attain a high-speed, highly accurate measurement by using 3-D image measurement system proposed here. In this text, I aimed to demonstrate the application example applied to the probable, man-machine interface and the security field because of its usage of practicable 3-D image measurement system.

II. 3-D SHAPE MEASUREMENT

A method of triangulation was the radical principle of 3-D image measurement based on the pattern light projection. The pattern light was projected from the projector to the measurement object, and it took a picture of the appearance from a different angle with the camera. Do as formula 1 to calculate the depth distance

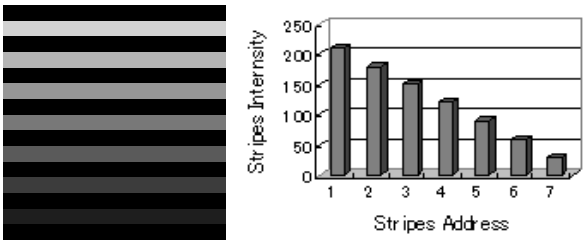


Fig.1. Intensity modulated pattern

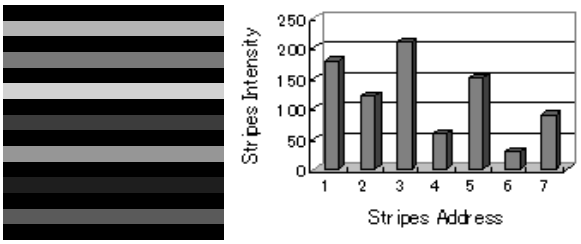


Fig.2. Optimal intensity modulated pattern

of measurement point from projection angle of pattern stripes and stripe coordinate on the observation image.

$$z = \frac{b}{\tan a + \tan b} \tag{1}$$

Here, z was a depth distance of the measurement point; b was a base length (the distance between source of light and the center of lens of camera); a was stripes projection angle; ß was an observation angle degree; b was known among these; ß was computable by stripes coordinates on the observation image.

When the strength modulation pattern light was used as shown in Fig 1, stripes projection angle could be calculated by a single piece of picture theoretically. However, influenced by the surface color of the measurement object and reflection, the intensity value of the projection stripes in the observation image changed and the correspondence to the projection angle collapsed. There was an optimum strength combination pattern light projection method to solve such a problem. It was a technique to optimize projection pattern and to seek for regulation of variations in intensity at a maximum about intensity difference of projection between adjacent stripes.

In a set of stripes addresses $\{1,2,\mathrm{K}\ ,N\}$, when the intensity order of the address $p_i \in \{1,2,\mathrm{K}\ ,N\}$, the projection light intensity of the stripes strength order was defined as the following magnitude correlations.

$$I_{\min} \le I_{p_1} \le I_{p_2} \le \Lambda \le I_{p_N} \le I_{\max} \tag{2}$$

Here, I_{p_i} is the projection light intensity of stripe address, $I_{\min}$ and $I_{\max}$ are minimum value and maximum value of the projection light intensity respectively. The function was defined when the projection light intensity difference of the stripes strength distribution combination $(I_1, I_2, \mathrm{K}\ I_N)$ was at the maximum, evaluation function $d(I_1, I_2, \mathrm{K}\ I_N)$ was also at the maximum.

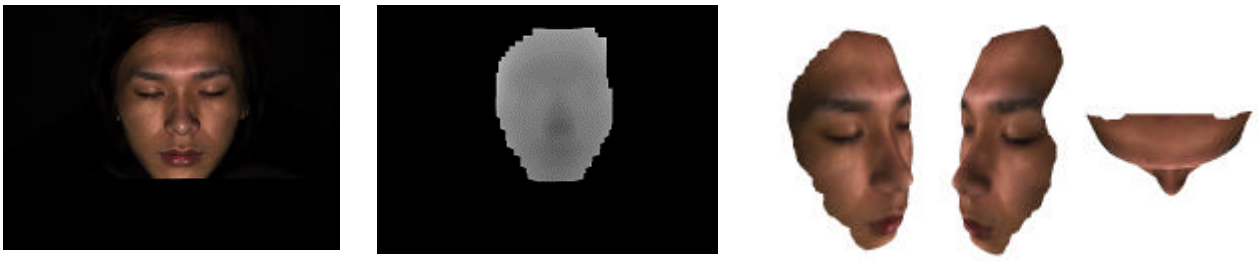
$$d(I_1, I_2, \mathrm{K}\ I_N) = \sum_{i=M+1}^{N} \sum_{j=1}^{M} k_j \left| I_i - I_{i-j} \right| \tag{3}$$

Here, kj was a weight factor. M was width of the filter on which evaluation function has been set. As the relation of formula 2, when $d(I_1, I_2, \mathrm{K}\ I_N)$ was at the maximum, $d(p_1, p_2, \mathrm{K}\ p_N)$ amounted to the same thing. Thus, it can be said that $d(p_1, p_2, \mathrm{K}\ p_N)$ seek combination $(p_1, p_2, \mathrm{K}\ p_N)$ at the maximum as its optimum combination. Projection pattern shown in Fig 2 was replaced by the stripes order of projection pattern in Fig 1. We knew that the strength difference between adjacent stripes has been increasing as graph. As a result, stripes projection angle should be computable accurately as long as the strength change rule was maintained even if the error margin was included in the detection of stripes projection light intensity.

III. APPLICATIONS

1. Face Detection

Face detection is to detect the direction that human is facing. As the computer can automatically do face detection, it can be used to find out something deserved to be paid attention to and to be under watch without looking the other way during travels. Man's face does movement by rotating from top to bottom of the neck right and left. Therefore, to understand the direction of the face accurately, 3-D information on the face is needed. This time, 3-D image of the face can be acquired by using 3-D shape measurement proposes it. 2-D color information and 3-D shape information are included in 3-D image. First of all, we extracted the face organs such as both eyes and noses by using 2-D color information, and then calculated the inclination angle in the frontal direction by using 3-D position relation of the face organs.



(a) Color image (b) Range image (c) 3DCG

Fig.3. 3D-shape measurement result

2. Face Authentication

2-D image was to take a picture of the object with the digital camera and record information on the shade, brightness, and vividness, etc. While 3-D image recorded information on a three-dimensional size, position, and shape what the object originally has, which was useful for the depth change and the curved surface inspection. That was difficult for 2-D image to analyze.

Face recognition used traditional 2-D image made it easy to come about misidentification as a result of influences like face position, expression, make-up, and lighting environment, etc. For the factors stated above, it can be expected that robust recognition should be practicable by using 3-D face image. Now, 3-D face image can be acquired by using 3-D image measurement system proposed here. It corresponded to the variation of face by generating the distance image vector from face on all sides by way of 3-D image and studying each person's range image through subspace method [4].

The range image sample for study was showed in the sets of the image vector. Here, *m* was a product of width and the height of the range image, *n* was the number of range image samples.

When L was projected to the partial space, the basis vector in which the error of mean square was minimized was calculated by the KL conversion. As an unknown range image vector was projected to the partial space, if it were a same person, the projection vector length should grow. Therefore, certification should be done by requesting the projection vector length to a partial space as a degree of similarity with the registration character.

IV. RESULTS AND DISCUSSION

Various objects were measured by using 3-D image measurement systems which was used the optimal intensity-modulation projection technique. Fig 3(a) was a color image of the measurement object taken with camera. Fig 3(b) was a range image expressed by light and shade from the projector. It was clear that 3-D coordinates were calculated in each pixel. Fig 3(c) was an expression of 3-D shape of the object with 3DCG. From the outcome of experiment, we have known that the measurement concerning 3-D shape of the target object can be done in a high sensitivity from the counting system that mounted the optimal intensity-modulation projection technique. Moreover, single-projection could shorten the processing time and the measurement to the dynamic object like human should be practicable. Comparing the size of a columnar object with the depth distance of the measurement result, measurement accuracy was evaluated, which resulted in about 0.3mm of the average error margin and 0.8mm or so of the maximumerror margin.

The sample data used to experiment on face recognition was 3-D image of 15 subjects who acquired it by using 3-D shape measurement system. The direction of the face was changed from the front, the right, and upward. 3-D image of the frontal face was assumed to be registration data, and the range image for 125 kinds of faces was generated for the design of a partial space. Unknown input data was collated with the registration data 1 to 1, and the occurrence rate of similarity degree was calculated respectively in person among classes. Fig 4 showed the distribution of the frequencies of similarity degree. A large value was taken when it was a person himself, and if it were others, it should be taken a small value. The threshold to

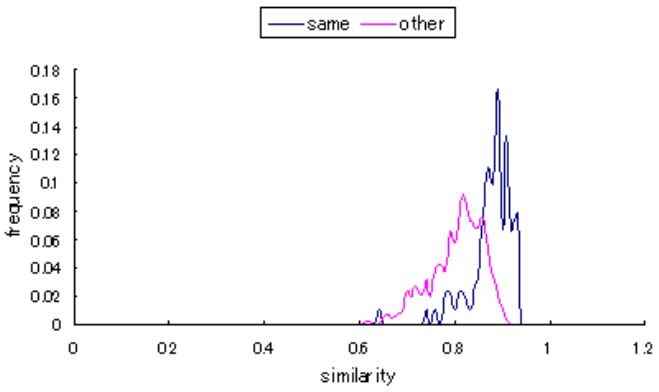


Fig.4. Frequency of similarity

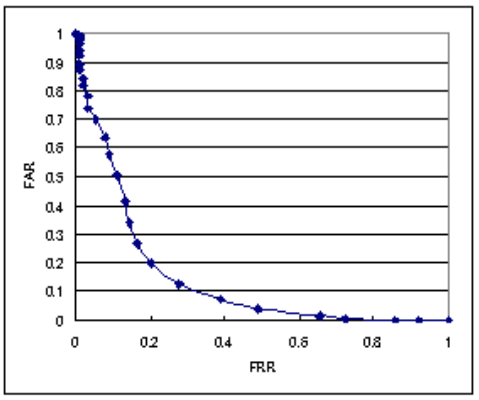


Fig.5. ROC curve

distinguish one person himself from the others was assumed to be a parameter, and misidentification certificate rate FRR and FAR were calculated respectively. The result was shown in ROC curve of Fig 5. From frequency distribution of similarity degree in Fig 4, the case that similarity degree in the others' group was high. It was thought that a common feature with others was extracted by designing a partial space, and the difference between one people himself with the others was vague. Moreover, because the change for the face of the learning pattern was set within 20 degrees in the turning angle, it was difficult to correspond to the change for a face.

However, because it had possibility of extracting the same feature among different people when the turning angle degree of the learning pattern was raised and the number of distance images was increased, it was necessary to improve the method of designing a partial space. It differed from the subspace method that used the color image as another cause, and personal characteristics were valued in the area where the depth change in the face surface shape was intense in the subspace method that used the range image. It was thought that personal characteristics had decreased on the other hand though the worry that ambient light and the make-up influenced disappeared because the range image is separated from the feature of color information based on the color strength difference like eyes, eyebrows, and the skins.

V. CONCLUSION

The practical use of 3-D image measurement was anticipated in the manufactory field. In my study, I aimed to introduce practical 3-D image measurement system with the use of possible and optimum strength modulation pattern light projection method to carry out a high-speed, high sensitivity measurement. Moreover, as an application of measurement system, with the use of face detection and recognition, I am looking forward to demonstrate the correspondence to 3-D movement so as to compensate something troublesome like make-up and lighting for 2-D image. In the present study, it proposed the technique for generating the regularized distance image from 3-D face measurement data as feature data used for the collation processing. As a result, because the feature data separated from color information on the face was obtained, the attestation technique for not receiving the influence of outside ambient light was able to be achieved. Moreover, an invariable attestation became a position variation with possible by the constant generation of the distance image of the size of the face that did not depend on the position of the measurement apparatus with the person and the face registration by the nose top coordinates of the range image. In the present study, the subspace method of the range image was applied to the problem of the change for the face of multiple degrees of freedom.

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