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THREE-DIMENSIONAL MEASUREMENT APPROACH FOR AUTOMATIC SEAL IMPRESSION IDENTIFICATION

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ABSTRACT

A new approach is proposed in order to construct a practical automatic identification system for seal impressions. The 3D (three dimensional) measurement method is investigated to select a suitable measurement system for seal registration. The seals are measured as 3D image by employing the range finder system. The pre-processing is performed to correct the slight slant on the measured seal surface. Special attention is paid to deal with the variety in impression quality using the measured 3D image. Impressions affixed under various conditions are reconstructed by transforming the measured image to impressions. The effect of the proposed method is verified by experiments.

1 INTRODUCTION

In Japanese society, seal identification have been widely used for identifying a person, a social group and so on. Recently, attending with the boom of the social structure, seal identification has become too heavy for human-eyes and an automatic identification system is required. In practical impression identification, it is the core of the problem to deal with variety in impression quality of a seal. The variety of the impression quality is caused by the changes of the imprinted conditions.The imprinted conditions must be well-considered when an impression is identified. Conventional methods [1]-[8] have tried to absorb the variety through checking if the input impression can match the reference one,the registered impression measured as 2D image. However, these methods have not turned to practical use widely. The matching techniques based on 2D reference impressions appear not feasible enough to cope with so many changes in quality. As one of the factors, we consider that we cannot obtain enough informations only from a 2D reference image itself to find the conditions which the identified impressions were imprinted under. In fact, an input impressions imprinted under limited conditions with high quality were required for experiments in most of the methods based on 2D reference impression. In the actual work of seal identification, there are almost no such limits. Moreover, there are various impression quality. Generally in the 2D matching method, the preciser result is expected the closer affixed conditions are required.

This paper proposes a new approach to deal with the variation of impressions. Here, a seal is measured as 3D image instead of 2D image in conventional methods, and we will show that various impressions imprinted under different conditions, such as the slant, the pressure and the painted state, can be reconstructed by only one 3D reference image. It means that we can identify an impression by examining if there is the match in the impression set generated by the 3D reference image.

We employ a range finder system [9][10] for measuring the seal as 3D image. Range finder system is a measurement system which can get the shape of 3D objects as range information. It has been used as eyes of robot, CAD/CAM, and so on. Recently, there are remarkable improvements on measuring accuracy, it is expected to be using as accurate measurement system for the seal registration. Generally, most of the measured images have some slight slant. A pre-processing is performed by using Hough transformation [11] to extract the surface of the seal exactly and correct the slant on it. The available 3D image is transformed to 2D image matching the input impression by adjusting the parameters in Hough transformation, which express the affixed conditions respectively. The experiments show that the reconstructed reference impressions are obtained well-matched the input ones.

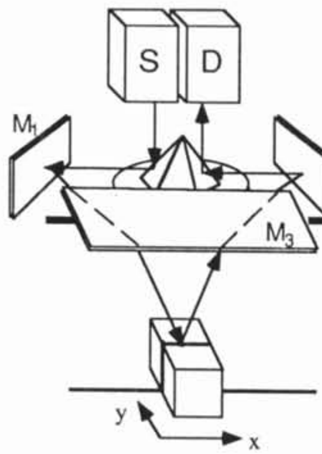


Figure 1: The construction of the range finder system of NRCC.

In the remaining sections, we shall discuss the measurement method, the correction method, the impression construction method and the experimental results respectively.

2 MEASUREMENT

In this section, we shall discuss the characteristics of the range finder system and describe a measurement method.

The range finder system has been classified into two types, one uses the "time-of-flight surveying method" and the other uses the "triangular surveying method". In the time-of-flight surveying method, there are "radar method" and "phase difference detect method". The radar method surveys the time-of-flight of a optical pulse which reaches the object and backs immediately. The phase difference detect method calculates the time-of-flight from the difference of the optical pulse phase. These methods have an advantage of that the measurement accuracy is independent of distance. However, they will become more complex and expensive when they realize the short time-of-flight precisely. So it is mainly used for measuring a long distance.

The range finder system based on triangular surveying method consists of a projector and a camera which measures the position of the light from the projector on the object. The distance to the object can be calculated using a triangle constructed by the projector, the camera and the position of the light. As the light sources, the spot light, slit light and step light are usually used. These methods can measure with high confidence especially for short distance, since the laser is used as a light source. Therefore, we consider that it is suitable for measuring seals regards as accuracy. Please note that it is desirable to use a high resolution range finder system to satisfy the seal measurement accuracy.

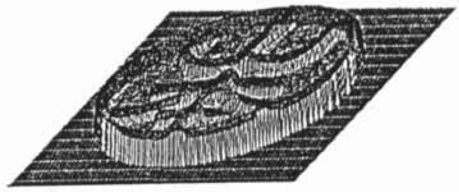


Figure 2: The bird's-eye view of a seal measured by using the range finder system.

In this paper, a range finder system [9][10] developed by NRCC (National Research Council Canada) is used as measurement system. The construction of this system is shown in Fig.1 This system is based on triangular surveying method and consists of a spot light scanner and a PSD (Position Sensitive Detector). It can measure range with a few micron scale. The beam started from laser source is diffracted by pyramid mirror which rotates at high speed, then it is reflected by fixed mirror M_1 and deflection mirror M_3, and it is floodlighted on object. It scans the x-axis by pyramid mirror and the y-axis by deflecting mirror. The reflection light is spotted on PSD sensor D by symmetrical optical system. At that time, the range information is got from the position information of beam created on sensor. The range information is represented by 3D coordinates (x, y, z) based on homogeneous coordinate, and z-value for sampling point of equal interval on x-y axis is range data [10].

Fig.2 shows the bird's-eye view of a seal measured by using the range finder system.

3 SLANT CORRECTION

In this section, we shall discuss the characteristics of seal's 3D image, and describe the method for pre-processing.

Since it is difficult to maintain the seal surface perpendicular just right with the observed direction in measurement procedure, seal is often measured with a little slant. Hough transformation, which is often used to extract out the lines or patterns in a picture, is extended to 3D space for correcting the slant. A plane defined on orthogonal coordinate can be transformed into θ-ϕ-ρ parameter space as:

$$\rho = X\cos\phi\cos\theta + Y\cos\phi\sin\theta + Z\sin\phi. \quad (1)$$

Here, ρ is the range from the origin of coordinates to the plane, ϕ is the inclination of the perpendicular line of the plane on x-y plane, and θ is the angle between x-axis and the projection of the perpendicular line on x-y plane. Similar to the case of 2D Hough transformation, there will be a peak point in θ-ϕ-ρ space corresponding to the plane defined on orthogonal coordinates and the plane can be extracted by finding the peak point. In the seal case, let $(\theta_0, \phi_0, \rho_0)$ be the extracted point, the seal surface can be expressed as:

$$\rho_0 = X\cos\phi_0\cos\theta_0 + Y\cos\phi_0\sin\theta_0 + Z\sin\phi_0. \quad (2)$$

Since $\sin\phi_0 \neq 0$, eq.(2) can be rewritten as form as:

$$z_H = ax + by + c. \quad (3)$$

The corrected image can be obtained as:

$$z'_L = z_L - z_H. \quad (4)$$

Here, z_L is the measured image.

4 IMPRESSION CONSTRUCTION

In this section, we shall describe the method for constructing 2D impression from 3D image.

As discussed in Section 3, eq.(2) means the seal surface detected from the 3D image. In the equation, by shifting the degree of slant ϕ, the direction of slant θ and the range ρ with $\Delta\phi, \Delta\theta$ and $\Delta\rho$ respectively, we can get a plane as:

$$z'_H = a'x + b'y + c', \quad (5)$$

where

$$\begin{aligned} a' &= -\frac{\cos(\phi_0+\Delta\phi)\cos(\theta_0+\Delta\theta)}{\sin(\phi_0+\Delta\phi)}, \\ b' &= -\frac{\cos(\phi_0+\Delta\phi)\sin(\theta_0+\Delta\theta)}{\sin(\phi_0+\Delta\phi)}, \\ c' &= \frac{(\rho_0+\Delta\rho)}{\sin(\phi_0+\Delta\phi)}. \end{aligned}$$

Then by using the plane z'_H and the measured image z_L, we can get a new 3D image $d(x,y)$ as:

$$d(x,y) = (z_L - z'_H)_+, \quad (6)$$

where

$$(\alpha)_+ = \begin{cases} \alpha & ,\alpha \geq 0 \\ 0 & ,\alpha < 0 \end{cases}$$

$\Delta\phi$, $\Delta\theta$ and $\Delta\rho$ indicate the degree of the slant, the slant direction and the pressure respectively. The 2D seal impressions can be obtained from this 3D image by binarizing.

By the way, if a seal is affixed with too much paint, the strokes of the seal can be enlarged. The cause of enlargement is that seal's paint spreads by the affixing pressure. In this case, first we get a 3D image $d(x,y)$. Then the spread 3D image $g(x,y)$ can be obtained as:

$$g(x,y) = \iint_{-\infty}^{\infty} d(u,v)e^{-\frac{(x-u)^2+(y-v)^2}{d(u,v)}}dudv. \quad (7)$$

Eq.(7) means that the bigger $d(x,y)$ at point (x,y) is, the stronger and the more widely it affects around.

5 EXPERIMENTAL RESULTS

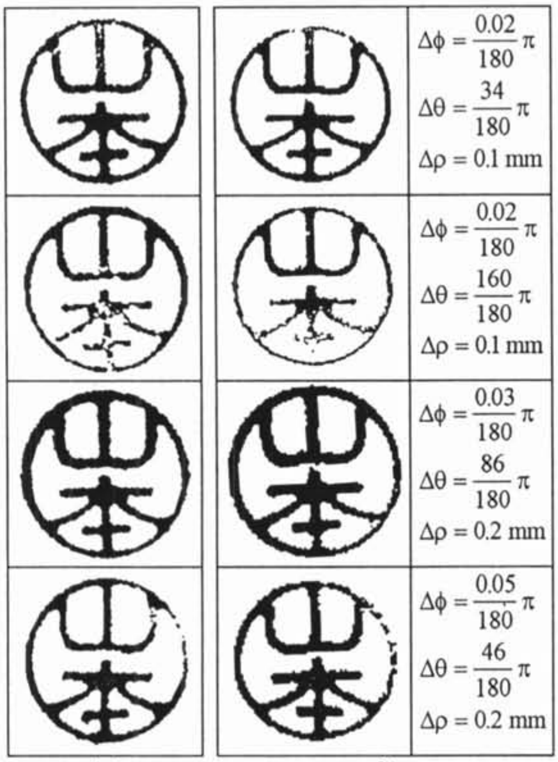
In this section, the effect of the proposed method is verified by experiments.

The 3D images are measured using range finder system mentioned in Section 2. As the materials, eighteen seals obtainable at the market are used. The seals are round which have the diameter from 9mm to 11mm. There are made of plastic and wood. The plastic is white and the wood is black. In the experiment, the seals are fixed with plaster in a metallic box. In addition, to prevent the absorption of light and secondary reflection, the seal surface is painted with frosting spray. Sampling space of x-y axis is 0.05mm, and the accuracy of z axis is 0.005mm. That means a seal is measured in 256×256 pixels.

Hough transformation is used to extract seal's surface from the measured 3D image. Considering the characteristics of the 3D image practically, we determine the interval of Hough transformation as follows: θ is from 0 to 2π, ϕ is from $\pi/4$ to $\pi/2$. Here, the quantizing resolution of parameters θ, ϕ and ρ are decided depending on the requirements of correcting accuracy. In this experiment, the resolution of θ and ϕ is decided as $\pi/160$ and the resolution of ρ is 0.1mm.

If we store the corrected data directly as binary image, more than 270 Kbyte data space is required. The authors had proposed a data compression method for 3D data using piecewise polynomial approximation [12]. By using the compression method, 3D data can be compressed and stored with small quantity.

We shall discuss the constructed 2D seal impressions from the 3D images. The seal is measured slantingly. The detected parameters of seal's surface are as follows: $\theta_0 = 34/180\pi$, $\phi_0 = 87/180\pi$, $\rho_0 = 32.8$mm. The effectiveness of the constructed impression is discussed by comparing them with the affixed impressions. The impressions affixed on paper are taken into computer by image scanner with 600 DPI. The scanned image of impressions are shown in Fig.3(a). For these impressions, selecting parameters closed to the affixed impressions by a rough estimate and some trials, and we could create impressions which should have similar affixing conditions. Figure 3 shows that we can obtain a image very similar to the affixed impression by adjusting a few parameters. This shows that very accurate identification and valuation will become possible using



(a) (b)

Figure 3: Experimental results.

(a) *Seal impressions affixed in several conditions.*
(b) *Generated impressions from one 3D image and generating parameters.*

3D information than using 2D information as reference impression.

6 CONCLUSIONS

It is possible to register a seal as 3D image by using range finder system. Since the solution space of an input impression can be decided structurally with a 3D model, the impression variety can be absorbed by the method of impression reconstruction. It is a further research to verify the performance of the present method objectively from a viewpoint of automatic identification.

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