A ROBUST SEAL IMPRINT VERIFICATION METHOD WITH ROTATION INVARIANCE

Takenobu Matsuura and Kenta Yamazaki

Department of Communications Engineering, Tokai University
1117 Kitakaname, Hiratsuka, Kanagawa 259-1292 Japan
phone: + (81) 463 58 1211, fax: + (81) 463 58 8320, email: matsuura@dt.u-tokai.ac.jp

ABSTRACT

This paper presents a robust seal imprint verification method with rotation invariance. The rotation invariant feature is represented by the absolute value of Fourier coefficients of log-polar image of seal imprint on circles with different radii. Firstly, the feature vector of a seal imprint is defined by the above absolute value of Fourier coefficients of the log-polar image. Secondly, the feature vector is expanded into Karhunen-Loeve (K-L) expansion. Thirdly, seal imprint is verified using the distance between vectors defined by coefficients in K-L expansion corresponding to true and given seal imprints. Finally, seal imprint verification experiments are given to show the effectiveness of the proposed method.

1. INTRODUCTION

Seal imprint has been commonly used for personal confirmation in Japan and some Asian countries. Seal imprints appear on many types of documents, such as bank cheques, receipts, etc. Most of seal imprint verifications have been made by visual inspection of human being. In order to make the verification for large numbers of seal imprints automatically, some methods have been proposed [1, 2, 3], which are mainly based on a matching of skeletons of character strokes. In those methods an adjustment of rotation angle for seal imprint was required in the matching procedure. It is not so easy to make the adjustment of rotation angle. It is desirable to realize a simple verification system without the adjustment of rotation angle. A method using Zernike moments without any adjustment of rotation angle was proposed [5]. However it was rather difficult to verify a seal imprint with complicate character because of computation complexity of the moments. In the paper [4] it was reported that the seal imprint verification by a personal computer provided better results than those by human being, but no discussion was made about the rotation of seal imprint. While a technique treating seal in three-dimensions (3D) was proposed [3]. In the method, it is not easy and very complicate to adjust rotation angle and the consideration about stained seal imprint still remain as future work. Another seal imprint verification method with rotation invariance was proposed [6]. The method provided good verification results for rotation and stains of seal imprint, but it was not good for blurred seal imprints.

In this paper, a robust seal imprint verification method with rotation invariance is proposed to improve the above disadvantage. The rotation invariant feature is represented by the absolute value of Fourier coefficients of log-polar image [7, 8] of seal imprint on circles with different radii. The feature vector of a seal imprint defined by the absolute value of the Fourier coefficients of the log-polar image is expanded into Karhunen-Loeve (K-L) expansion [9]. Then seal imprint is verified using the distance between vectors defined by coefficients in K-L expansion corresponding to true and given seal imprints.

2. FEATURE EXTRACTION

In this section, first, after a seal imprint has been represented as an image of 64 x 64 pixels with 256 gray levels by digital scanner, the seal imprint is represented by 2D continuous function in Cartesian coordinate as

$$f(x,y)=\sum_{n=0}^{P}\sum_{m=0}^{P} f(n,m)\phi(x-n,y-m) \tag{1}$$

where

$$\phi(x,y)=\frac{\sin \pi x}{\pi x}\cdot\frac{\sin \pi y}{\pi y} \tag{2}$$

and P is an integer related to the image size. $f(n,m)$ is a gray level at a pixel (n,m) on the seal imprint. Then the following function is defined by letting

$$x=r^{\rho/L}\cos\frac{2\pi t}{L},\ y=r^{\rho/L}\sin\frac{2\pi t}{L}$$

in (1) as

$$\hat{f}(\rho,t)=f(r^{\rho/L}\cos\frac{2\pi t}{L}, r^{\rho/L}\sin\frac{2\pi t}{L}) \tag{3}$$

where, $0\le\rho\le 1,\ 0\le t\le 2\pi$ and $\hat{f}(\rho,t)$ is defined inside of the circle of radius $\rho=1$ [6, 7, 8]. An example of a log-polar mapping of seal imprint is shown in Fig.1. Furthermore it is assumed here that without loss of generality, $\hat{f}(\rho,t)$ is a periodic function as

$$\hat{f}(\rho,t)=\hat{f}(\rho,t+2m\pi) \tag{4}$$

for any integer m. Under the assumption the log-polar image $\hat{f}(\rho,t)$ is expanded into Fourier series by letting $\rho=\rho_k$(constant) as

$$\hat{f}(\rho_k,t)=\sum_{m=-\infty}^{\infty} a_m^{(k)}e^{jmt} \tag{5}$$

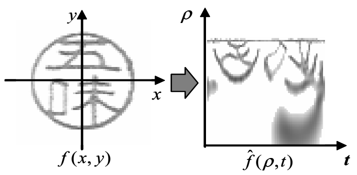


Figure 1: A log-polar mapping of seal imprint

where

$$a_m^{(k)} = \frac{1}{2\pi}\int_0^{2\pi} \hat{f}(\rho_k, t)e^{-jmt}dt \qquad (6)$$

Let $\hat{g}(\rho, t) = \hat{f}(\rho, t + \alpha)$ be the rotated seal imprint of $\hat{f}(\rho, t)$ by angle α about its origin. Then it can be seen that the Fourier coefficients $b_m^{(k)}$ of $\hat{g}(\rho_k, t)$ is given as

$$b_m^{(k)} = a_m^{(k)} e^{jm\alpha}. \qquad (7)$$

Thus we have the following relation:

$$\mid b_m^{(k)} \mid = \mid a_m^{(k)} \mid \qquad (8)$$

This shows that the absolute value of the Fourier coefficients of log-polar image of seal imprint is rotation invariant. Seal imprint is often contaminated with noise

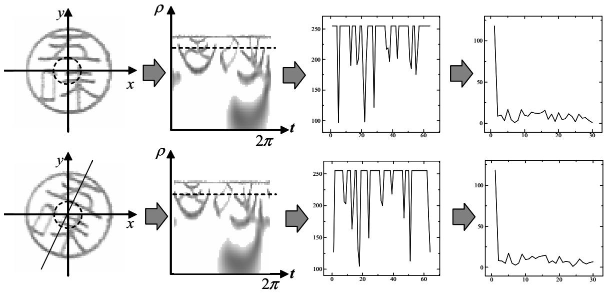


Figure 2: The absolute value of the Fourier coefficients of seal imprints contaminated with noise due to rotation.

due to the rotation, stain and blur. In practice a log-polar image of seal imprint on circles with different radii can be represented by the truncated Fourier series as

$$\hat{f}(\rho_k, t) = \sum_{m=-K}^{K} a_m^{(k)} e^{jmt} \qquad (9)$$

The absolute value of the coefficients of the truncated Fourier series for seal imprints contaminated with noise due to the rotation ,stain and blur are given in Fig.2,Fig.3 and Fig.4, respectively. Figs.2-4 show that the absolute value of the coefficients of the truncated Fourier series are stable for seal imprints contaminated with noise.

It can be seen from (6) that

$$a_0^{(k)} = \frac{1}{2\pi}\int_0^{2\pi} \hat{f}(\rho_k, t)dt \qquad (10)$$

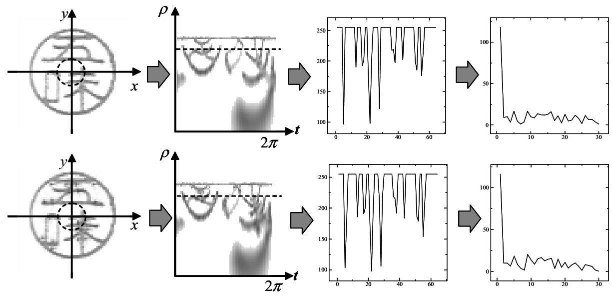


Figure 3: The absolute value of the Fourier coefficients of seal imprints contaminated with noise due to stains.

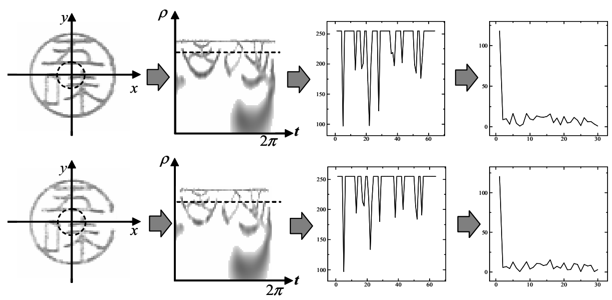


Figure 4: The absolute value of the Fourier coefficients of seal imprints contaminated with noise due to blur.

represents the total sum of the gray levels of the log-polar image of the seal imprint on the circle with a radius. It is considered that the gray levels of the imprints of a seal on the circle with a radius are different. In the seal verification it is desirable to normalize the total sum of the gray levels. In our method the first component is normalized as $\hat{a}_0^{(k)} = 1$. Then the feature vector of the seal imprint is defined by the Fourier coefficients as

$$\mathbf{a}'_k = [\mid \hat{a}_1^{(k)} \mid, \cdots, \mid \hat{a}_K^{(k)} \mid], \ (k = 1, \cdots, N) \qquad (11)$$

where

$$\hat{a}_m^{(k)} = \frac{a_m^{(k)}}{a_0^{(k)}} \qquad (12)$$

and $\mathbf{a}'_k$ denotes the transposition of $\mathbf{a}_k$. Furthermore define the covariance matrix of $\mathbf{a}_k$ as

$$C_k = E\{(\mathbf{a}_k - \overline{\mathbf{a}}_k)(\mathbf{a}_k - \overline{\mathbf{a}}_k)'\} \qquad (13)$$

where

$$\overline{\mathbf{a}}_k = E\{\mathbf{a}_k\} \qquad (14)$$

and $E\{\mathbf{a}_k\}$ denotes mean vector. The eigen vectors corresponding to the eigen values of covariance matrix C are calculated as

$$C_m \mathbf{u}_m^{(k)} = \mu_m^{(k)} \mathbf{u}_m^{(k)}, \qquad (m = 1, 2, \cdots, M) \qquad (15)$$

where

$$\mu_1^{(k)} > \mu_2^{(k)} > \cdots > \mu_M^{(k)}, \ (M < K),$$

$\mu_m^{(k)}$ and $\mathbf{u}_m^{(k)}$ are the eigen value and the corresponding normalized eigen vector, respectively. The feature vector $\mathbf{a}_k$ of the seal imprint can be expanded into K-L expansion as

$$\mathbf{a}_k - \overline{\mathbf{a}}_k = \sum_{m=1}^{M} c_m^{(k)} \mathbf{u}_m^{(k)} \tag{16}$$

where

$$c_m^{(k)} = (\mathbf{a}_k - \overline{\mathbf{a}}_k)' \mathbf{u}_m^{(k)} \tag{17}$$

Furthermore vectors are defined as

$$\mathbf{h}'_m = [c_m^{(1)}, \cdots, c_m^{(N)}], (m = 1, \cdots, M) \tag{18}$$

With the above vectors $\mathbf{h}_m$, a seal imprint is verified by the distance between vectors, $\mathbf{h}_m^{ref}$ and $\mathbf{h}_m$ corresponding to true and given seal imprints, respectively.

3. VERIFICATION ALGORITHM

It is assumed here that the mean value $\overline{\mathbf{a}}_k^{ref}$ of the feature vector $\mathbf{a}_k^{ref}$, the eigen vectors $\mathbf{u}_m^{(k)}$ corresponding to the eigen values $\mu_m^{(k)}$ of the covariance matrix C_k, $\mathbf{h}_m^{ref} = [c_m^{ref(1)}, \cdots, c_m^{ref(N)}], (m = 1, \cdots, M)$ and η (threshold value) for a reference seal imprint have been evaluated beforehand. The verification algorithm is given below:

(**Algorithm**)

(1) Calculate the Fourier coefficients $a_m^{(k)}$ of log-polar image of a given seal imprint and the feature vector:

$$\mathbf{a}'_k = [\mid \hat{a}_1^{(k)} \mid, \cdots, \mid \hat{a}_K^{(k)} \mid]$$

(2) Calculate the coefficients:

$$c_m^{(k)} = (\mathbf{a}_k - \overline{\mathbf{a}}_k^{ref})' \mathbf{u}_m^{(k)}, \ (m = 1, \cdots, M)$$

and the vector:

$$\mathbf{h}'_m = [c_m^{(1)}, \cdots, c_m^{(N)}].$$

(3) Verify the seal imprint as true if

$$\sum_{m=1}^{M} \| \mathbf{h}_m^{ref} - \mathbf{h}_m \| < \eta$$

otherwise false,
where $\| \mathbf{h}_m \|$ means Euclidean norm of $\mathbf{h}_m$.

4. EXPERIMENTS

In our experiment, 960 seal imprints belonging to 32 classes with variations such as rotation, stains with ink, blur and so on were used. As the experimental results, verification error rate(average) was 0.24%. Seal imprint is represented as image of pixels with a pixel of 8 bits. Some examples of the seal imprints are shown in Fig.5.

For convenience of explanation, it is assumed that the

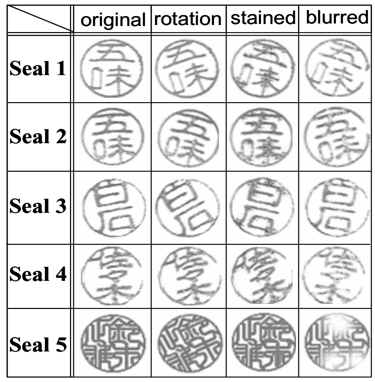


Figure 5: Some examples of the seal imprints

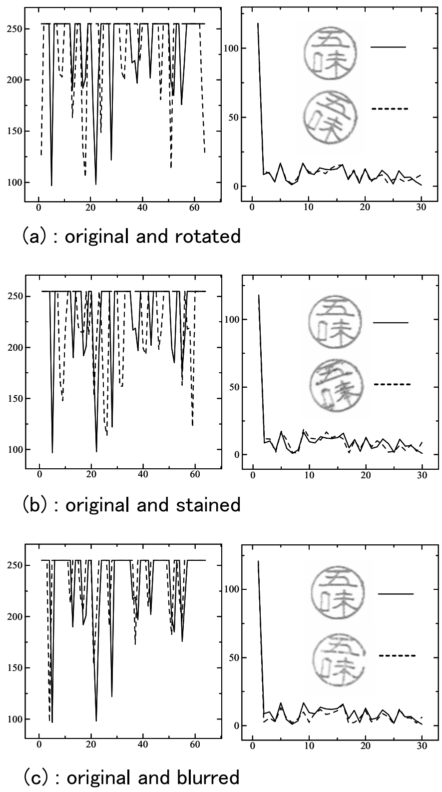
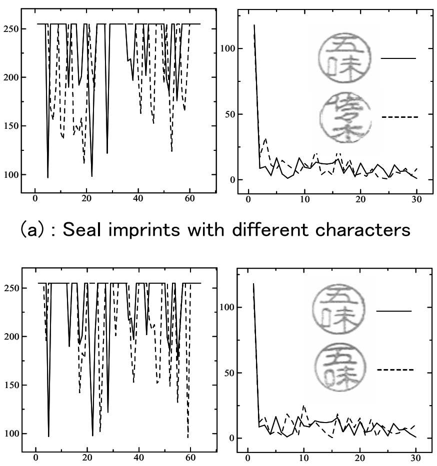


Figure 6: log-polar images of seal imprints on circles with a same radius and the absolute values of Fourier coefficients of the log-polar images



(a) : Seal imprints with different characters

(b) : Seal imprints with same character but different fonts

Figure 7: log-polar images of seal imprints on circles with a same radius and the absolute values of Fourier coefficients of the log-polar images

upper imprint in Fig.6 and Fig.7 is the reference imprint of a registered seal in the experiments. In usual seal imprint verification, the seal imprints shown in Fig.6 should be verified as the imprints of the registered seal, however the seal imprints shown in Fig.7 should be verified as different imprints of the registered seal. In Fig.6 and Fig.7, log-polar images of seal imprints on circles with a same radius and the absolute values of Fourier coefficients of the log-polar images are shown. It can be seen from Fig.6 that the absolute values of Fourier coefficients of the log-polar images are very close to those of the reference seal imprint. This shows that the feature vector in our method is robust for the rotation, stain and blur of seal imprints. On the other hand it can be seen from Fig.7 the absolute values of Fourier coefficients of the log-polar images are quite different from those of the reference seal imprint. This shows that the feature vector in our method is effective for describing the difference between seal imprints with not only different characters but also different fonts. An example of seal imprints verification for $M = 1, K = 30, N = 2$ is shown in Fig.8.

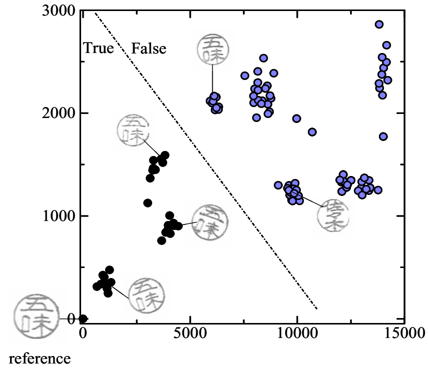


Figure 8: An example of seal imprints verification

5. CONCLUSION

This paper proposed a robust seal imprint verification method with rotation invariance. First, a log-polar image obtained from seal imprint represented as two-dimensional continuous function in Cartesian coordinate was expanded into 2D Fourier series. The rotation invariant feature was represented by the absolute value of Fourier coefficients of log-polar image of seal imprint on circles with different radii. Then the K-L expansion of the feature vector defined in terms of Fourier coefficients of log-polar image was used to obtain a vector representing the feature of a seal imprint. Furthermore the vector was used to evaluate the difference between the features corresponding to true and given seal imprints. It was found from the experimental results that the proposed method is robust for seal imprint verification.

REFERENCES

[1] Lee.S.W,and Kim.J.H: "Attributed stroke Graph Match-ing for Seal Imprint Verification", Pattern Recognition Lett..Vol.9,No.2,pp.137-145,Feb,1989

[2] Hiroshi MIENO: "An Experiment of Identification of Seal Impression by pattern Matching", Mar.1975

[3] Ryoji HARUKI,Takahiko HORIUCHI: "Automatic Seal Impression Identification Using 3-Dimensional Reference Seals",IEICE,,D-II.J82-D-II No.11 pp.2000-2007 Nov .1999.

[4] Katsuhiko UEDA: " Experimental Analysis of Factors Influencing the seal-Imprint Verification" IEICE,D-II Vol.J72-D-II ,No.1, pp.66-75 Jun . 1989

[5] T.matsuura and K.mori: "Rotation Invariant Seal Imprint Verification Method", ICECS2002,Vol.3,pp.955-958,Sep,2002

[6] T.matsuura and K.Yamazaki: "Seal Imprint Verification Method with Rotation invariance",APCCAS2005,IEEE pp.597-600 ,2004.12

[7] Kazunori SUGAHARA, Yuuichi SHIRAGA, Ryosuke KONISHI: "Complex-Log Mapping Approach to Digital Image Rotation and Enhancement or Reduction and its per-formance Evaluation", technical report of IEICE DSP 95-32,1995-05

[8] V.Javier Traver, Filiberto Pla: "Dealing With 2D transla-tion estimation in log-polar imagery", Image and Vision Comput 1 ,pp. 145-160, 2003

[9] J.T.Tou, R.G.Gonzalez: "Pattern Recognition Principles", Addison-Wesley Co.,pp.271-283,1974