Registration of Seal Images Using Contour Analysis

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Abstract. Many types of noise can be present in an image. Registration becomes difficult when the concerned pattern contains a "seal noise." In this paper, the seal noise appearing inherently in a seal image is introduced. The registration of seal images used widely in many commercial applications in Chinese society is presented. An effective approach using contour analysis for finding the principal orientation of a seal image is developed for the registration task. Three types of seal image of the author's own are used for experiments, and results obtained by a moment-based method are given for comparison.

1 Introduction

In Chinese society, seals are usually used instead of signatures [1], which are adopted for identity proving in the Western countries on many types of articles, e.g. paintings, proposals, money withdrawing lists, checks, receipts, etc. In the past, many pattern recognition techniques have been proposed for the seal identification, e.g., the use of fluency function approximation and relaxation matching method [2], the implementation of "hardmatching" principle [3], etc. The quality of seal imprint is strongly related to the paper's material, the setting pressure, and the orientation of setting the seal. Due to these factors, in practical, the resultant seal images are usually ill-posed, thus we give the name "seal noise" appearing in a seal image (see Fig. 1 for reference). Furthermore, based on the hardmatching principle on the characteristics of seal identification [3], any preprocessing for the seal image, such as the feature vectorization which will affect the original geometrical property, is not recommended. Therefore the registration of seal image becomes an important task before performing the seal identification.

In [3], two-step approach (computing the center information of seal image and performing the correlation under *rq*-domain) is used for registration. The center information depends strongly on the found minimum circular region covering the entire seal imprint. However, under the real case of seal noise involved (see Fig. 1(r) for example), this method will fail. It seems that many traditional techniques may also been applied to such a task, such as the moment-based method [4] and Fourier descriptor [5]. However, the moment invariants are only in reasonably close agreement for the geometrically modified versions of the same object. It is not suitable to

J. Bigun and T. Gustavsson (Eds.): SCIA 2003, LNCS 2749, pp. 255–261, 2003.

be applied for the current case with seal noise. Similarly the Fourier descriptor is usually to be applied to the shape analysis possessing continuous closed curve. Accordingly, in the following, we will present an effective approach based on the contour analysis for the registration task. A known moment-based method, called *best-axis* method [4], is also implemented for comparison.

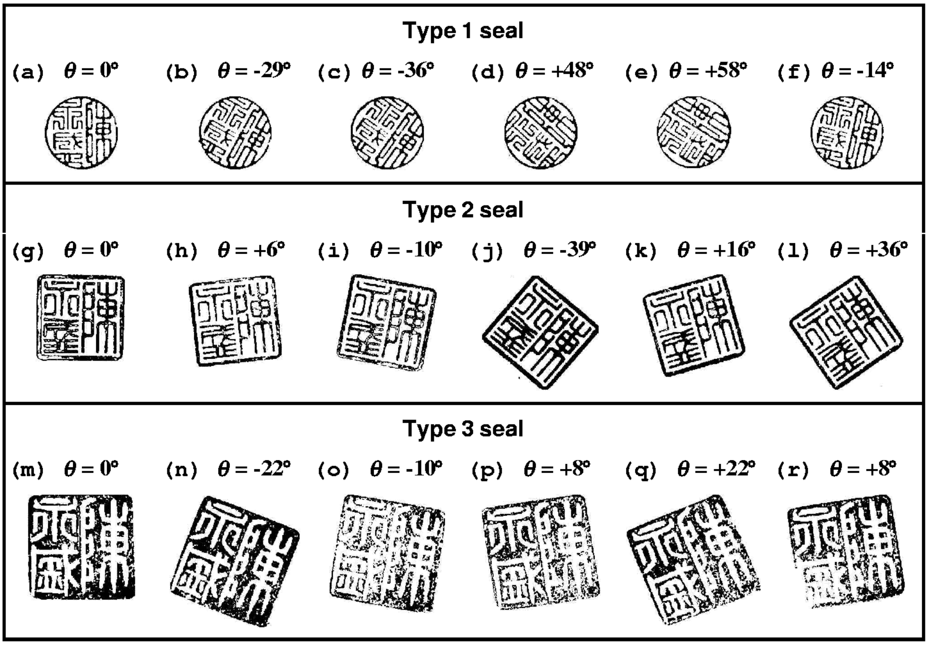

Fig. 1. (a-f) Type 1 seal. (g-l) Type 2 seal. (m-r) Type 3 seal.

2 Proposed Approach

The binary seal image scanned by a scanner (HP ScanJet 4c was used and the resolution was set to be 300 dpi) is represented as a 2-D matrix $[f]$ whose (x, y)th element is pixel $f(x, y)$, where x and y denote spatial coordinates; $f(x, y) = 0$ and $f(x, y) = 1$ are represented as a black pixel and a white pixel, respectively. In usual, the seals used in the Oriental countries may be circular or rectangular in shape, and may be male-type or female-type in engraving process. To demonstrate our approach for seal registration, three types of seal images of the author's own were used and are displayed in Fig. 1. Where the circular-male engraved seals are regarded as Type 1, the rectangular-male engraved seals are regarded as Type 2, and the rectangular-female engraved seals are regarded as Type 3, respectively. Note that the so-called "seal noise" appears very heavy in the Type 3 images; and some stroke information disappears in Type 2 and Type 3 images. To facilitate the later comparison, we define the first image of each Type to be reference and set its base degree to be 0, i.e., $q = 0°$. The rotated degree of each other image with respective to the reference was measured by protractor, where minus and plus symbols denote right-rotation and left-rotation, respectively. In the following, the images in Fig. 1(a) and 1(b) will be used to illustrate the proposed approach.

A binary image [*f*] can be described by its contour information, and represented by a finite set of contour chains, C_i, $i = 1, 2, \ldots, m$. The *k*th contour pixel of the *i*th contour chain is denoted by $C_i(k)$, and whose coordinate is denoted by $(x_{C_i(k)}, y_{C_i(k)})$. The length of a contour chain can be obtained by counting the number of pixels along the contour. According to the geometrical property of seal processing mentioned previously, the significant seal information should be preserved for identification [3]. This implies that a contour chain having longer length possesses a more significant seal information. Hence we define a threshold (= 50 was used in our experiments) to filter out the contour chains whose length smaller than the threshold. And the set of contour chains will be reduced to C_i, $i = 1, 2, \ldots, n \le m$. Based on these definitions, we let $TA_i(k)$ denote the tangent angle for the *k*th contour pixel in the *i*th contour chain, which may be obtained and expressed by

$$TA_i(k) = \tan^{-1}\left(\frac{y_{C_i(k+\Delta)} - y_{C_i(k-\Delta)}}{x_{C_i(k+\Delta)} - x_{C_i(k-\Delta)}}\right) \quad \textbf{(1)}$$

Where $C_i(k+\Delta)$ and $C_i(k-\Delta)$ denote the next Δth and the previous Δth contour pixel, respectively, based on the current contour pixel. In order to produce the angle histogram and for further detection of principal orientation, all the *TA*s are transformed into integer degrees ranged from 0° to 179°. Figure 2(a) and 2(b) show the contour information and the angle histogram respectively for the seal image given in Fig. 1(a), where the color information is used to label the corresponding *TA*. The top point, (q, h), of each bar in the angle histogram denotes there exist h contour pixels having $TA = q$. Note that each angle histogram has been normalized such that the maximum peak is $h_p = 255$.

From the angle histogram of Fig. 2(b), a peak is apparently observed due to the stroke property for a seal. However, the principal orientation (*PO*) of a seal image may be affected and changed within a local range due to the effect of "seal noise." Hence in order to determine a more reasonable *PO* for a seal image, the angle information in a local angle range $[q_l, q_r]$ is considered. Here q_l and q_r denote respectively the second maximum peak at the left side (towards to 179°) and right side (towards to 0°) neighboring to the maximum peak q_p. To filter out the small values, we take the mean value $h_{th} = \left[\sum_{\forall q} h(q)\right]/180$ as a threshold. The candidate of second maximum peak should be larger than h_{th}. Based on the notations, we have the main useful data, $h_{th}^{ref} = 27$, $(q_l^{ref}, h_l^{ref}) = (95^\circ, 135)$, $(q_p^{ref}, h_p^{ref}) = (90^\circ, 255)$, and

$(q_r^{ref}, h_r^{ref}) = (84^\circ, 104)$, in Fig. 2(b) for the seal image of Fig. 1(a), which will be regarded as a reference for the further illustrations.

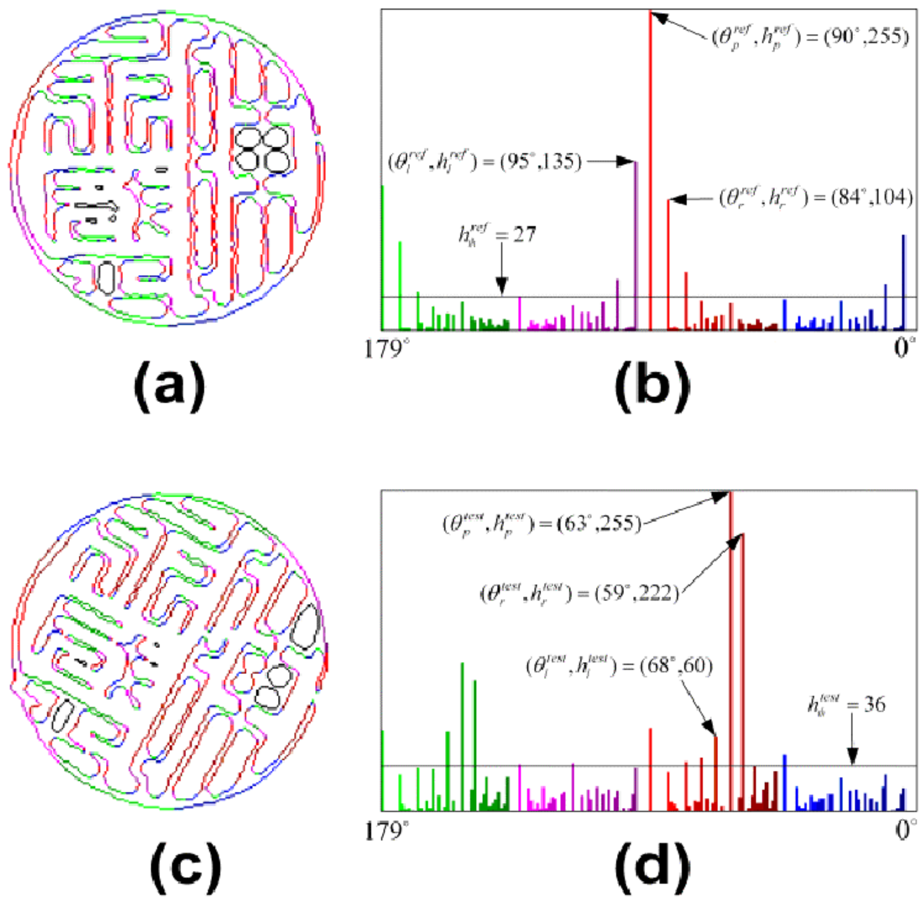

Fig. 2. (a, b) Contour information and angle histogram for seal image in Fig. 1(a). (c, d) Contour information and angle histogram for seal image in Fig. 1(b).

According to the property of angle histogram for a seal image, $PO \in [q_l, q_r]$, and to make the *PO* information more robust, we modify the angle histogram in the range $[q_l, q_r]$ as below

$$\tilde{h}(q) = \begin{cases} h(q_l), & q_l \geq q > q_p, \\ h(q_p), & q = q_p, \\ h(q_r), & q_p > q \geq q_r; \end{cases} \tag{2}$$

and construct the cumulative distribution function (*cdf*) for the new angle histogram in the range $[q_l, q_r]$. The *PO* of a seal is thus defined by the q having the 50th percentiles of the *cdf*, that is,

$$PO = \left\{ q_{50\%} \middle| cdf(q_{50\%}) = \left[\sum_{q \in [q_l, q_r]} \tilde{h}(q) \right] / 2 \right\} \tag{3}$$

Based on Eq. (3), we found $PO_{ref} = 91^\circ$ for the seal image of Fig. 1(a). Figure 2(c) and 2(d) show the another results of test seal image in Fig. 1(b). The found principal orientation is $PO = 61^\circ$. Hence the corresponding degree for registration (from reference one to test one) may be expressed by

$$\Delta PO = PO_{test} - PO_{ref} \tag{4}$$

In the current case, $\Delta PO = 61^\circ - 91^\circ = -30^\circ$ is obtained by the proposed approach.

3 Results and Conclusion

Let the reference binary seal be denoted as BS_{ref} and the test one be denoted as BS_{test}, respectively. The rotated version of BS_{ref} based on Eq. (4) is denoted as RBS_{ref}. To complete the registration task, the translation vector $\vec{V}$ from RBS_{ref} to BS_{test} should be determined. Since the range of a seal is previously known, it is easy to find a centered window in RBS_{ref}, which may match closely to a desired centered range in BS_{test} using template matching.

Let W and H be the width and height of RBS_{ref}, $W/2$ and $H/2$ are used for the centered window so that an enough seal information can be used for template matching. In addition, let $\left(x_{ref}^{center}, y_{ref}^{center}\right)$ be the center point of RBS_{ref}, and the found best-match window in BS_{test} will have its center point $\left(x_{test}^{center}, y_{test}^{center}\right)$. Based on the translation vector $\vec{V}$ from $\left(x_{ref}^{center}, y_{ref}^{center}\right)$ to $\left(x_{test}^{center}, y_{test}^{center}\right)$, a new version $TRBS_{ref}$ translated from RBS_{ref} may be used to overlap with BS_{test} and thus display the seal registration for visual inspection. Figure 3 shows the registration results for the three types of seal images given in Fig. 1 using the proposed approach. The performance measurement given in Table 1 shows that the average error of our method is about 1.13°.

Since such a rotation registration problem may be performed by a moment-based method, for the sake of comparison we also apply one well-known method finding the "best axis" for an object to all the seal images in Fig. 1. The registration results are shown in Fig. 4 and Table 1, where the average error is 12.95°. Based on the experimental results and comparison, the effectiveness and feasibility of the proposed approach have been confirmed.

As a conclusion, a registration method using contour analysis to deal with seal images containing "seal noise" has been presented. Our experiments show that the registration result is valuable for further processing, such as human visual inspection in a bank checker assistant system and seal identification system.

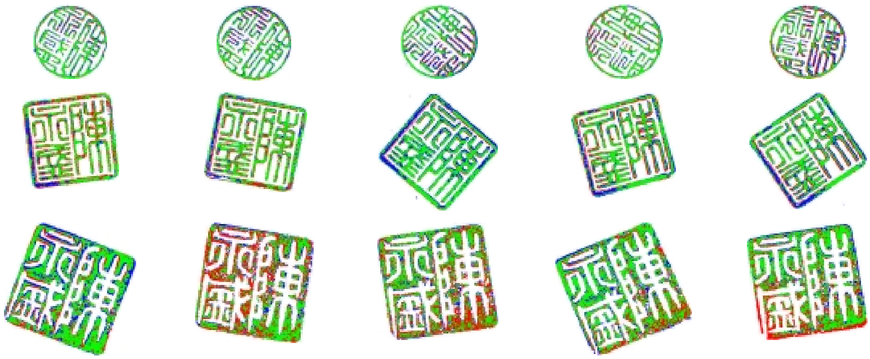

Fig. 3. Registration results using the proposed approach.

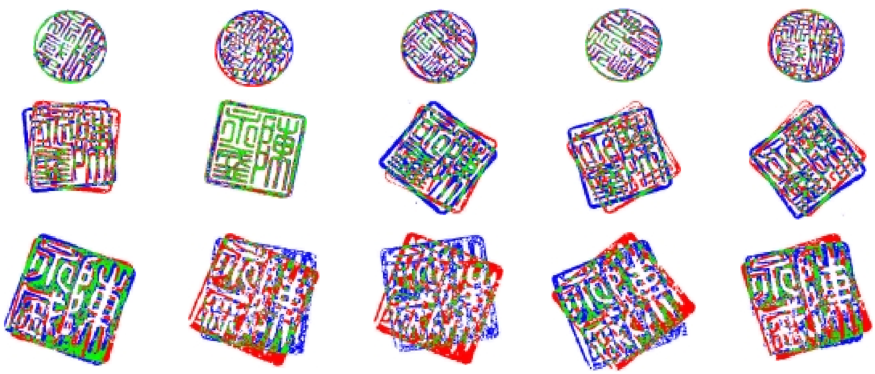

Fig. 4. Registration results using the moment-based method [4].

Acknowledgments

This work was supported partially by Startek Engineering Inc. in Taiwan, ROC.

Table 1. The results of our method compared with those of the known moment-based method [4].

Registration pair	Degree measured by protractor	Proposed method		Moment-based method [4]	
		degree	error	degree	error
Fig. 1(a)→1(b)	-29°	-30°	1°	-33.5°	4.5°
Fig. 1(a)→1(c)	-36°	-35°	1°	-7.2°	28.8°
Fig. 1(a)→1(d)	48°	46°	2°	37.6°	10.4°
Fig. 1(a)→1(e)	58°	57°	1°	52.8°	5.2°
Fig. 1(a)→1(f)	-14°	-15°	1°	3.5°	17.5°
Fig. 1(g)→1(h)	6°	8°	2°	-5°	11°
Fig. 1(g)→1(i)	-10°	-10°	0°	-10.9°	0.9°
Fig. 1(g)→1(j)	-39°	-40°	1°	-25.9°	13.1°
Fig. 1(g)→1(k)	16°	15°	1°	31.7°	15.7°
Fig. 1(g)→1(l)	36°	34°	2°	47.9°	11.9°
Fig. 1(m)→1(n)	-22°	-20°	2°	-16.3°	5.7°
Fig. 1(m)→1(o)	-10°	-9°	1°	-23.9°	13.9°
Fig. 1(m)→1(p)	8°	7°	1°	-21.2°	29.2°
Fig. 1(m)→1(q)	22°	23°	1°	38.5°	16.5°
Fig. 1(m)→1(r)	8°	8°	0°	17.9°	9.9°

Average error = 1.13 **Average error = 12.95**

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