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Postmark Date Recognition Based on Machine Vision

LIU Ying-Jie, YOU Fu-Cheng

Information & Mechanical Engineering School,Beijing Institute of Graphic Communication
Beijing, China
liuyingjiea@hotmail.com, youfucheng@bigc.edu.cn

Abstract

For the purpose of information management on postmark according to the date, the paper put forward a method of postmark date recognition based on machine vision, which could meet the demands of personal postmark collectors. On the basis of the relative theories of machine vision, image processing and pattern recognition, the overall process is introduced in the paper from postmark image acquisition to date recognition. Firstly, threshold method is used to generate binary image from smoothed postmark image. So region of date numbers could be extracted from binary image according to different region features. Then regions of date numbers which are connected or broken could be processed through mathematical morphology of binary image. Individual regions of date numbers are obtained for recognition. Finally, classification and pattern recognition based on support vector machine make date numbers classified and date recognition is implemented correctly.

Index Terms—machine vision， postmark date， mathematical morphology， pattern recognition

Introduction

With the development of postal industry, various sorts of postmarks have been published for different purposes. Most of postmarks are collected by lots of personal postmark collectors due to their considerable cultural and historical value. However, with the increasing number of collection, manual operation and management on postmarks increase accordingly. It is also disadvantageous to the preservation of postmark value. Therefore, information management on postmarks by computer to reduce manual workload becomes the urgent problem to be solved. It is the practical demands of personal collectors that postmarks of different historical periods are managed automatically according to their dates.

Under this background of practical demand, plenty of experiments on postmark date recognition are performed. Then taking an example of typical postmark, a method of postmark date recognition based on machine vision is introduced systematically in this paper. Thereby a kind of standard framework of information management on postmarks according to the date is established and could provide to personal postmark collectors in practical applications.

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Postmark Image Acquisition System Based on Machine Vision

A. Framework of Machine Vision System

Fig. 1 displays the postmark image acquisition system based on machine vision. The system is composed of machine vision hardware and software.

The components of machine vision hardware include CCD (charge-coupled device) camera with planar array, light resources of standard illumination, image grabber and computer for information processing. Machine vision software mainly deals with the postmark images that grabbed by hardware and performs the date recognition.

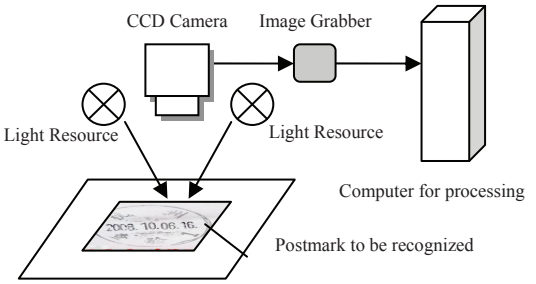

Figure 1. Machine Vision System

B. Function Description of Machine Vision System

Place the postmarks under CCD camera and standard light resources. Make the date of postmark parallel to the axis of camera for the convenience of latter processing. The advantage of CCD camera with planar array is that its fill factor maximizes the sensitivity of the image pixels to light and minimizes aliasing.

On condition of homogeneous and fixed illumination, postmark images are acquired by CCD camera with planar array. The camera delivers postmark images to computer through image grabber (camera-computer interface). The device driver of the camera-computer interface assembles the images in the computer memory. Then postmark image processing and date recognition are implemented by machine vision software through computer.

Algorithm of Postmark Image Processing

C. Postmark Image Pre-processing

In most situations, postmark image contains some degree of noises. So the postmark image acquired by machine vision system is always blurred. If date numbers are recognized correctly, high quality pre-processing image is the important premise. Therefore, smooth the postmark image firstly so that the noises in the image could be suppressed by some kind of smoothing filter.

Among all smoothing filters, the linear Gaussian filter is the optimal smoothing filter not only because it could suppress high frequencies, i.e., noises, in the image but also it is rotation-invariant, i.e., isotropic [1]. Let the row and column of image be denoted by r and c. Let σ be denoted by the standard deviation. Then the Gaussian filter in two dimensions is defined by (1).

$$g_\sigma(r,c) = \frac{1}{2\pi\sigma^2} e^{-(r^2+c^2)/(2\sigma^2)} \tag{1}$$

Gaussian filter suppresses high frequencies much better than other smoothing filters. So it is usually the preferred smoothing filter due to the optimal noise suppression, if the quality of the results is the primary concern.

D. Postmark Image Segmentation and Number extraction

It is fairly important for image processing and number recognition to generate the binary image through some threshold operation. Effects of threshold operation have direct influence on the final results. Therefore, appropriate threshold method according to the practical condition is the key point. If the postmark image after smoothing by Gaussian filter is specified as local background, regions of date could be characterized by being locally darker than their local background. So optimal segmentation could be achieved by dynamic threshold and regions of date could be extracted easily.

Dynamic threshold is an operation that compares the image to its local background. Let the postmark image be denoted by $f_{r,c}$ and the smoothed image be denoted by $g_{r,c}$. Then the dynamic threshold for dark regions is defined by (2).

$$S = \{(r,c) \in R \mid f_{r,c} - g_{r,c} \le -g_{diff}\} \tag{2}$$

From the binary image that generated by dynamic threshold, regions of date are segmented obviously. Irrelevant regions are suppressed based on the features such as height, area, aspect ratio and so on. Thereby regions of date numbers could be extracted from the binary image.

E. Morphological Image Processing on Connected and Broken Numbers

Regions of date numbers which are extracted from binary image are usually not the individual number regions, but connected or broken in practice. The solutions are morphological image processing for above mentioned problems. The regions which are connected or broken should be extracted firstly according to their region features. Then the connected or broken regions could be dealt with respectively by the algorithms of mathematical morphology.

1) Mathematical morphology of binary image

Mathematical morphology is based on set theory. For the purpose of image analysis and recognition, structuring element (set) is used to modify and extract the corresponding shape in the image. Fundamental operations of mathematical morphology include dilation, erosion, opening and closing [2]. Suppose A denotes a region (set), B denotes a structuring element. Specify an origin of B as the reference of morphological operation.

The dilation of region A by structuring element B, denoted $A \oplus B$, is defined by (3). Equation (3) is based on obtaining the reflection of B about its origin and shifting this reflection by x. The dilation of A by B then is the set of all displacements, x, such that reflection of B and A overlap by at least one element [3].

$$A \oplus B = \{x \mid [(\hat{B})_x \cap A] \subseteq A\} \tag{3}$$

The erosion of region A by structuring element B, denoted $A \ominus B$, is defined by (4). Equation (4) indicates that the erosion of A by B is the set of all points x such that B, translated by x, is contained in A.

$$A \Theta B = \{x \mid (B)_x \subseteq A\} \tag{4}$$

Thus it can be seen that dilation expands a region and erosion shrinks it. Dilation and erosion are fundamental operations of morphological processing. In fact, many of the morphological algorithms are all based on these two primate operations. If the same structuring element is used in combination of dilation and erosion, the operations are called opening and closing.

Opening generally smoothes the contour of a region, breaks narrow connections, and eliminates thin protrusions. The opening of region A by structuring element B, denoted $A \circ B$, is defined by (5). Thus, the opening of A by B is the erosion of A by B, followed by a dilation of the result by B.

$$A \circ B = (A \Theta B) \oplus B \tag{5}$$

Closing also tends to smooth region contours but, as opposed to opening, it generally fuses narrow breaks and long thin gulfs, eliminates small holes, and fills gaps in the contour. Similarly, the closing of region A by structuring element B, denoted $A \bullet B$, is defined by (6). The closing of A by B is simply the dilation of A by B, followed by the erosion of the result by B.

$$A \bullet B = (A \oplus B) \Theta B \tag{6}$$

2) Processing on connected region of numbers

For connected region of numbers, firstly eleminate the holes in the connected region by morphological algorithm of region filling. Then construct a rectangle structuring element, which could break the connection between numbers, according to the connected position and direction. The rectangle structuring element is used in opening operation on filled connected region. Thereby the connection is broken. Make the result intersect with the initial connected region. The individual regions of numbers are obtained then by intersection operation.

3) Processing on broken regions of numbers

For broken region of some number, firstly construct a structuring element, which could fuse the break of the region, according to the broken position and direction. Then the structuring element is used in closing operation on broken region. Thereby the broken region is connected. And the complete region of number is obtained.

F. Pattern Recognition Based on Support Vector Machine

Individual region of number need to be classified and recognized after segmentation and extraction by image processing. Therefore, some kind of classifier for number recognition needs to be chosen. In practice, the performance of classifier is determined by the size and quality of the training set. The results from practical applications indicate that Classification based on SVM (Support Vector Machine) exhibit enhanced generalization performance [4].

SVM method is based on statistical learning theory. Algorithm of SVM is implemented by a mapping from the input feature space into a higher dimensional space, where the classes can satisfactorily be separated by a hyperplane. The inner product of the vectors in the higher dimensional space has been expressed as a function of the inner product in the original feature space [5]. These inner products of transformed feature vectors are called kernels. Hence, the decision function given by (7) becomes a function of the kernel. The coefficient of the support vectors is denoted by α_i. The kernel is denoted by $k(x, x_i)$.

$$f(x) = \mathrm{sgn}(\sum_{i=1}^{m} \alpha_i y_i k(x, x_i) + b) \tag{7}$$

The ingenious trick of SVM classification is that the kernel can be evaluated without transforming the features into higher dimensional space, thus making the evaluation of the classification function feasible. Typical kernel used in pattern recognition applications is radial basis function which is defined by (8).

$$K(x, x_i) = \exp\{-\frac{|x - x_i|^2}{\sigma^2}\} \tag{8}$$

As advantages noted above, SVM classifier is chosen in postmark date recognition. Features that extracted from number regions form the training set. Then SVM classifier is trained. Thereby the classifier could make decision and implement the number recognition.

Since it is often difficult to obtain a training set with all variations, numbers from various postmarks should be added to training set as many as possible. Furthermore, to evaluate the classifier, a test set which is independent from the training set should be provided to determine the quality of the classifier.

Experiment and Result Analysis

Fig. 2 displays the flow chart of postmark date recognition system based on machine vision.

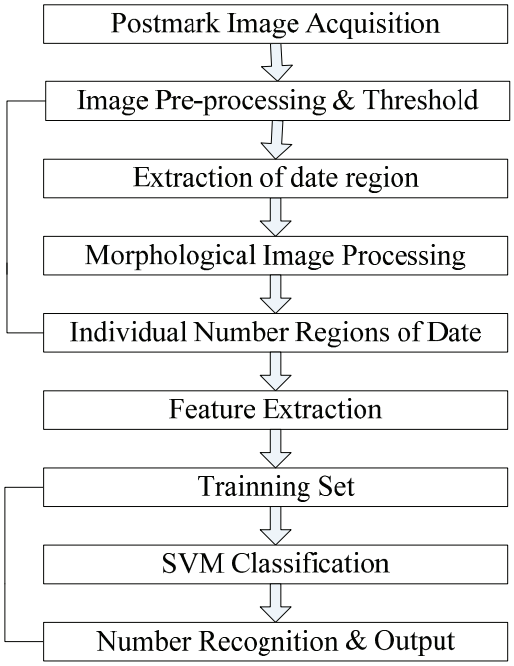

Figure 2. Flow Chart of Postmark Date Recognition system

The most typical postmark is selected from experiments as an example in the paper, which is little blurred and includes connected and broken numbers. The postmark image grabbed by machine vision system is shown in Fig.3.

G. Processing on Blurred Image

First of all, pre-process on blurred image. Smooth the postmark image by Gaussian filter. Then dynamic threshold operation is used to segment the image. The binary image obtained is shown in Fig.4.

Figure 3. Postmark Image Figure 4. Binary Image

H. Extraction of Date Region

Suppress irrelevant regions based on the features of height, area and aspect ratio. So the regions of date numbers could be extracted from the binary image as shown in Fig.5.

Figure 5. Regions of Date Numbers

I. Morphological Image Processing

It can be seen from Fig.5 that regions of number 2008 are connected; regions of number 2 and 6 are broken. The regions mentioned above should be extracted according to their region features firstly. Then the algorithms of morphology are used to deal with the connected and broken numbers respectively. Thereby the individual number regions could be segmented for recognition.

1) Processing on connected region of numbers

Connected region of number 2008 could be extracted by feature of aspect ratio, as shown in Fig.6. Then use algorithm of region filling to eliminate the holes in the connected region. The filled region is obtained as shown in Fig.7.

Figure 6. Connected Region

Figure 7. Filled Region

According to the connected position and direction of number 2008 in Fig.7, construct a rectangle structuring element 1 as shown in Fig.8. Then apply opening operation on the filled connected region by structuring element 1. Thereby the result of separate regions is shown in Fig.9. It can be seen that the connected region has been broken after opening operation by appropriate structuring element.

Figure 8. Structuring Element 1

Figure 9. Separate Regions

The remaining problem is number restoration. This can be corrected by intersecting the separate regions with the initial connected region. Fig.10 shows that, intersected regions of individual numbers are obtained by intersection operation. However, number 0 and 8 need to be further process due to their breaks. Then extract broken number 0 as shown in Fig.11.

Figure 10. Intersected Regions

Figure 11. Broken Number 0

Similarly, according to the broken position and direction in Fig.11, construct a structuring element 2 as shown in Fig.12. Then apply closing operation on the broken number 0. Thereby the result of individual number 0 is shown in Fig.13.

Figure 12. Structuring Element 2

Figure 13. Individual Number 0

Based on the above results, the two individual regions of number 0 could be subtracted from the initial connetced region of number 2008. Then broken number 2 shown in Fig.14 and individual number 8 shown in Fig.15 are obtained respectively by subtraction operation.

Figure 14. Broken Number 2

Figure 15. Individual Number 8

Thus, the connected region of number 2008 has been segmented to individual regions by algorithms of morphology.

2) Processing on broken region of numbers

It could be seen obviously from the broken number 2 shown in Fig.14 that a break exists in middle of the number region. Therefore the break needs to be fused. According to the broken position and direction of broken number 2 in Fig.14, construct structuring element 3 shown in Fig.16. Then apply dilation on the region of broken number 2 by structuring element 3. Thereby the dilation region without any break is shown in Fig.17. And the break has been fused after dilation by appropriate structuring element.

Figure 16. Structuring Element 3 Figure 17. Dilation Region

For the purpose of recognition, skeleton operation is applied to the dilation region shown in Fig.17. Then the skeleton of number 2 is obtained as shown in Fig.18. To restore the shape of number 2 more accurately, unite the skeloton and the broken number 2 shown in Fig.14. The union operation results in the individual region of number 2 as shown in Fig.19. It can be seen that the broken region has become the complete number region after morphological operations.

Figure 18. Skeleton Figure 19. Individual Number 2

As shown in Fig.5, the last number 6 of the date is also broken. Extract it as shown in Fig.20. Similarly according to its broken position and direction, choose appropriate circle as the structuring element. Then apply dilation on the region of broken number 6 by the circle structuring element. Thereby the region of individual number 6 without any break is shown in Fig.21.

Figure 20. Broken Number 6 Figure 21. Individual Number 6

Thus, the broken numbers of the date have been processed to form the individual complete regions by algorithms of morphology.

J. Number Recognition Based on Support Vector Machine

In last step, the segmented numbers should be classified and recognized, i.e., a class from 0 to 9 is assigned to each individual region of number. The classifier based on support vector machine is trained by the training set and evaluated by the test set. The SVM classifier then implements the classification and recognition of individual segmented numbers.

In Fig.22, the original postmark image, the individual segmented regions of numbers and the result of the number recognition are all shown together as the output. Note that all numbers of the postmark date have been recognized correctly.

Figure 22. Recognition Result

Conclusion

In this paper, better results have been achieved from the experiments on practical postmark images, which are based on the relative theories of machine vision, image processing and pattern recognition. Thereby a framework of postmark date recognition system based on machine vision is provided to personal postmark collectors in practical applications.

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