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# SwiftPost—A Vision-based Fast Postal Envelope Identification System

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***Abstract*—A vision-based fast postal envelope identification system for moving machine printed Chinese postal envelopes is proposed. Our system uses a high-speed camera to capture the image of envelopes running on the convey device and then recognizes the postal address and postcode on the envelopes. A vocabulary of 4590 categories of characters are supported, which include 4516 frequently used Chinese characters defined in GB2312-80, 62 alphanumeric characters, and 12 punctuation marks and symbols. The supported font styles include Song, Fang Song, Kai, Hei, etc. with the printed font size of no less than 7.5 points. The experimental results on 761 mail images representing 25,060 characters show that an envelope with an average of 32.9 characters can be processed and recognized within 81.38 milliseconds and the character recognition rate of postal address is 98.72%. Furthermore, our system also provides the function to store the envelope images and their recognition results into database in real time, which can be used in subsequent envelopes tracking and management. The experimental results with live mails on site indicate that our system can reach a speed of 21,000 mails per hour, and the character recognition rate of postal address is as high as 98.92%. Besides, our system can be conveniently equipped on the envelope processing devices in postal service center.**

***Keywords*—character recognition, real-time vision system, postal envelope identification**

## I. INTRODUCTION

Automatic postal addresses recognition is one of the most important applications of offline Optical Character Recognition (OCR)[1], which aims to automatic sorting of mail pieces or assigns a bar code in terms of recognized address for subsequent mail sorting, tracking and management. A typical automatic postal address recognition system mainly consists of five modules: (1) envelope image preprocessing, (2) address block location, (3) line/character segmentation, (4) character recognition, (5) address post-processing. Throughout the intensive research of last three decades, a great deal of improvement has been achieved in each sub-topic and several systems for postal addresses recognition are also available [2-12]. However, most of these works were mainly focused on handwritten address recognition. In practice, there are a lot of machine printed business mails that need to be processed daily in a very fast manner, for example around 30,000 envelopes per hour, to meet the requirement of postal automation. At present, except the system with a complex hardware structure in [2], no such a system that can satisfy this requirement is available in literature. Reference [13] presented an address block location method based on the connected components (CCs) for machine-printed Korean mail images with success rate of 96%, while it did not deal with sequent segmentation and recognition. In addition, experiments indicated that CCs based location method is quite time consuming and not suitable for our real-time mail image processing system. This research aims to provide a solution for high-speed high-precision machine-printed Chinese postal address recognition.

The present handwritten address recognition techniques cannot be directly applied in machine printed address recognition in that most of them emphasize on the recognition accuracy, thus the recognition speed is unsatisfactory. To improve the recognition accuracy, some handwritten address recognition system may use complicated algorithms with relatively lower processing speed, thus the complicated hardware systems are often needed to reinforce the system efficiency. For example, the remote computer read system in [2] contains 10 recognition processors to satisfy the processing speed of 90,000 envelopes per hour. For handwritten Chinese address recognition, the reported results in literature vary according to adopted recognition strategy and different hardware performance [6-9]. In a more recently published paper [7], Jiang et al. presented a system achieving a correct rate of 85.3% with the speed of 3 seconds per mail on 3GHz personal computer. In [9], Su et al. gave a system with the speed of 0.65 seconds per mail. Liu et al. described a lexicon-driven Japanese address recognition system where the processing of one mail can be done within around 110 milliseconds [10]. Japanese address recognition is a similar task in OCR field, however, above-mentioned processing time does not include that of address block location and text line segmentation. Furthermore, the system needs to construct an address lexicon database which is also a non-trivial task. On the other hand, the published character correct rates for handwritten Chinese address recognition is only around 76%-86% [7], [9], [10], and it should be noted that some of them do not consider the address block location errors. In [8], Han et al. published a correct sorting rate of 96.2% for handwritten Chinese mails. However, considering that present mail sorting

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in China may only be exact in Province/City name, not the street name, this result is far from satisfactory.

In this paper, a vision-based fast postal envelope identification system for moving machine printed Chinese postal envelopes is proposed. Our system uses a high-speed camera to capture the image of envelopes running on the convey device and then recognizes the postal address and postcode on the envelopes. A vocabulary of 4590 categories of characters are supported, which include 4516 frequently used Chinese characters defined in GB2312-80, 62 alphanumeric characters, and 12 punctuation marks and symbols. The supported font styles include Song, Fang Song, Kai, Hei, etc. with the printed font size of no less than 7.5 points. The experimental results on 761 mail images representing 25,060 characters show that an envelope with an average of 32.9 characters can be processed and recognized within 81.38 milliseconds and the character recognition rate of postal address is 98.72%.

Furthermore, besides the automatic address recognition, our system also provides the function to store the envelope images and their recognition results into database in real time, which can be used in subsequent envelopes tracking and management. The experimental results with live mails on site indicate that our system can reach a speed of 21,000 mails per hour, and the character recognition rate of postal address is as high as 98.92%. Besides, our system can be conveniently equipped on the envelope processing devices in postal service center.

The rest of this paper is organized as follows: Section 2 gives an overview of the proposed postal envelope identification system. Section 3 describes in detail the techniques used in our system, followed by the experimental results in section 4. Section 5 gives the conclusions.

## II. System Overview

The proposed postal address recognition system use a high-speed camera to capture the image of the envelope running on the conveyer belt of mail processing device, where the camera is triggered by a laser sensor. While the envelope arrives at the position under the camera that is detected by the laser sensor, the sensor sends an envelope arriving signal to trigger the camera to capture the image. Then, the envelope image is fed to a personal computer for image processing and recognition. The processing and recognition procedure includes the address block location, image binarization, skew detection/correction, line/character segmentation, feature extraction, character recognition, and recognition post-processing. After the processing and recognition, the results along with the corresponding envelope image are sent to a database on another personal computer in real time. The database can be used in subsequent envelopes tracking and management. Fig. 1a gives the block diagram of the proposed system.

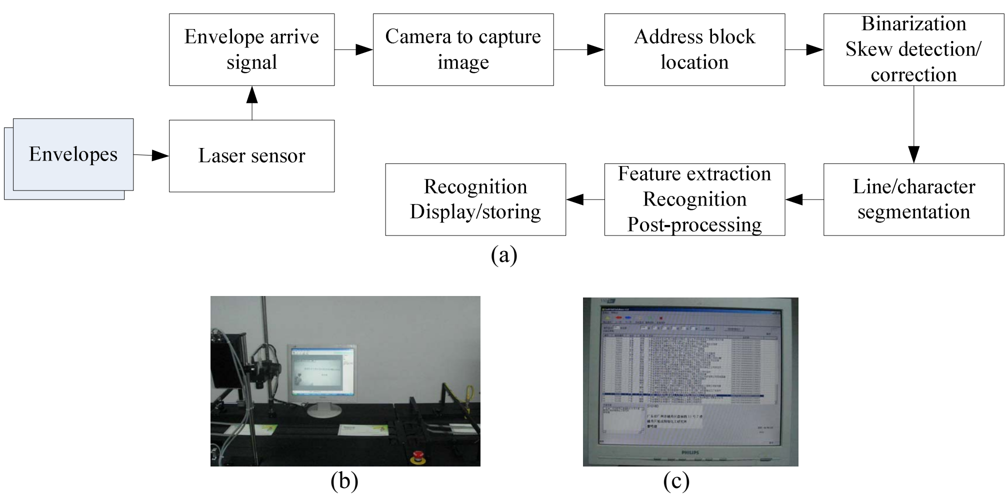


Figure. 1. Overview of the proposed system. (a) Block diagram of the system. (b) System setup. (c) Interface of recognition results database.

To capture the image of address contents on the fast moving envelopes, the envelope arriving signal should be as exact as possible. In our system, the position error given by the laser sensor is less than 5 millimeters, thus the envelope image can be obtained exactly. The captured image has a resolution of $640 \times 480$ pixels. Meanwhile, to avoid motion blur of the image, some light sources are needed for image enhancement.

## III. Methodology

To satisfy the need of real-time processing of moving envelopes in our system, the fast processing and recognition algorithms are needed to cooperate with the hardware system. In this section, we give the detail of methods used in the system.

### *A. Address Block Location*

The detection and location of address block in each envelope image is the first problem to solve. Our address block location algorithm is based on the following reasonable assumption: For each batch of envelopes to be processed, the layout and address block position are roughly the same. Although different batches of envelopes can have different address block positions, we can easily adjust the envelopes conveying devices and triggering time by laser sensor to ensure this assumption in each batch. For locating the edges of address block, we adopt the following algorithm.

For simplicity of illustration, we only give the procedure of locating the upper and lower edges here, and locating the left and right edges has the similar procedure. Let $f(i,j)$ be the gray value of pixel $(i,j)$, the horizontal gradient $gradh(i,j)$ is defined as equation (1). If $gradh(i,j)$ is more than a threshold $T_{gradh}$, then the pixel $(i,j)$ is considered as a stroke pixel. $T_{gradh}$ is determined by experiments. For each row $i$ of envelope image, we scan each pixel and count the number of the stroke pixels (denoted as $snh(i)$).

$$gradh(i,j) = abs(f(i,j-1) - f(i,j+1)) \quad (1)$$

Where $abs(.)$ means the absolute value.

Let $i_{maxsnh}$ be the row with maximum $snh(.)$, we scan from $i_{maxsnh}$ upward/downward respectively. If there exist $T_{bl}$ continuous rows whose $snh(.)$ is less than a threshold, the current row is set as the upper (or lower) edge of the address block. In our experiments, $T_{bl}$ is set to 50. The experimental results with a large amount of live mails indicated that our algorithm can locate the address block effectively with lower time consuming.

### B. Binarization and Skew Correction

Before the line/Character Segmentation can be done, the fast algorithms for binarization and skew detection/correction of envelope image is needed in our system. The binarization methods for document images have been explored extensively in several last decades, and which can be roughly grouped into global methods and locally adaptive methods [14], [15]. Generally, the global methods are faster, however, they are easily affected by the noises such as deficiency in illumination, exposure, etc. On the other hand, the locally adaptive methods are more effective, especially for resisting the image noises. In [15], Ye proposed a fast binarization method based on the local extreme value, which can be regarded as a modified version of Bernsen's locally adaptive methods. Our experimental results show that, this method gives the best result when both processing speed and recognition performance are considered. However, this algorithm costs 134.7 milliseconds for an image with a resolution of $640 \times 320$. This is not sufficient for our system. In this paper, we propose a binarization algorithm which combines the feature of the global method and the locally adaptive method. The basic idea is that, if the envelope image is divided into a few local sub-regions, and one global threshold is found for each sub-region, the problems of deficiency in illumination, exposure, etc. can be avoided to some extent. The algorithm is as follows:

Suppose that the envelope image $f(i,j)$ be divided into $N$ sub-regions $R(k), k = 1, \cdots, N$. For each sub-region $R(k)$, its binarization threshold is denoted as $T_{reg}(k)$, and its maximum and minimum gray values of pixels is $fmax(k)$ and $fmin(k)$ respectively. The threshold $T_{reg}(k)$ follows the equation (2). In our experiments, the size of sub-regions is set to $30 \times 30$.

$$T_{reg}(k) = \begin{cases} (fmax(k) + fmin(k))/2, & \text{if } fmax(k) - fmin(k) > T_1 \\ fmin(k), & \text{otherwise} \end{cases} \quad (2)$$

Where $T_1$ is a preset constant determined by experiments.

To keep the smoothness of the binarization thresholds of pixels in neighboring sub-regions, a linear threshold interpolation technique is applied as follows. Let $T_{img}(i,j)$ be the binarization threshold of pixel $(i,j)$ which belongs to sub-region $R(k_1)$ with the center coordinate $(i_1, j_1)$, $R(k_2)$ and $R(k_3)$ are the closest sub-regions of pixel $(i,j)$ in vertical and horizontal directions respectively, and the corresponding sub-region centers are $(i_2, j_2)$ and $(i_3, j_3)$. Then, we have equations (3-5).

$$T_{img}(i,j) = (TH_1(i,j) + TH_2(i,j))/2 \quad (3)$$

$$TH_1(i,j) = T_{reg}(k_1) + \frac{T_{reg}(k_2) - T_{reg}(k_1)}{i_2 - i_1}(i - i_1) \quad (4)$$

$$TH_2(i,j) = T_{reg}(k_1) + \frac{T_{reg}(k_3) - T_{reg}(k_1)}{j_3 - j_1}(j - j_1) \quad (5)$$

The experimental results show that our binarization algorithm costs only 1.18 milliseconds for an envelope image of $640 \times 320$ with satisfactory character recognition results. This is quite faster than Ye's method [15].

For skew detection, we use the projection profile based method, and the range is limited to±15°, the precision is set to 0.1°. The skew correction method proposed in [16] is used in our system, more detail can be found in the reference.

### C. Line/Character Segmentation

After the skew correction, we use the projection profile analysis based line segmentation method to locate the address lines in address block of envelope image. Once an address line is located, an over-segmentation strategy is adopted for character segmentation. More specially, for an address line, we first segment it into a sequence of sub-segments using projection profile. For those sub-segments of too small or too large, the aspect ratio, interval, maximum and minimum width constraints, and other heuristics about envelope layout are used to re-segment them sub-segments. From these sub-segments, a candidate segmentation paths network is constructed with each node representing a potential segmentation point, each arc representing the cost for that segmentation point in term of scores given by classifier. Finally, a dynamic programming algorithm is used in finding the best segmentation path together with its recognition result [17].

### D. Feature Extraction

The feature extraction is one of the most important modules that may affect the processing speed and recognition rate. In our system, we adopt two different feature extraction methods for performance comparison, respectively. One is the Gabor feature which is either based on the binary character image (denoted as GaborBin), or on the gray character image (denoted as GaborGray), and another is the gradient feature based on the gray character image (denoted as GradGray). The gray image based character feature can avoid the noises introduced by binarization procedure, thus may produce better recognition performance. The experimental results indicated that the gradient feature has better recognition rate with comparative processing speed. In the following, we explain briefly the feature extraction procedures for Gabor feature and gradient feature.

*1) Gabor Feature*

Gabor features have been widely used in many pattern recognition fields such face recognition, character recognition, etc. An important property of Gabor features is that they can achieve a joint optimal resolution in both the spatial and the spatial-frequency domains. In our system, we adopt the 2-D Gabor filter reported in [18], as shown in equations (6-8).

$$G(x,y;\kappa,\theta_k) = G_1(x,y)[\cos(R) - \exp(-\frac{\sigma^2}{2})] + iG_1(x,y)\sin(R) \quad (6)$$

$$G_1(x,y) = \frac{\kappa^2}{\sigma^2}\exp[-\frac{\kappa^2(x^2+y^2)}{2\sigma^2}] \quad (7)$$

$$R = \kappa(x\cos\theta_k + y\sin\theta_k) \quad (8)$$

Where $\kappa = \frac{2\pi}{\lambda}$ , $\theta_k = \frac{\pi k}{M}, k = 0,...,M-1$ , $\sigma = \pi$ ,and the parameters $\lambda$ and $\theta_k$ are the wavelength and orientation respectively. $M$ is the number of orientation, and it is set to 4 in our experiments.

Let $f(x,y)$ be the binary/gray character image，then we have Gabor feature for the sampling point $(x_0, y_0)$ as shown in equation (9) where $S$ is a constant parameter.

$$F_{\lambda,k}(x_0,y_0) = \left|\sum_{x=-S}^{S}\sum_{y=-S}^{S} f(x_0+x, y_0+y)G(x,y;\kappa,\theta_k)\right| \quad (9)$$

*2) Gradient Feature*

Gradient feature has been proven to be the most effective and time efficient feature in character recognition [19]. In our system, the gradient feature extraction is directly applied on the gray character image, thus the noises introduced by binarization procedure can be avoided.

To extract gradient feature, a $3\times3$ Sobel operators (as shown in Fig.2) is used to obtain the horizontal and vertical gradient at each pixel respectively. Then the character image is decomposed into a number of regions corresponding to $L$ directions with an equal interval $2\pi/L$ ( $L$ is set to 8 in our experiments), and the gradient vector of each pixel is assigned to its two nearest directions in a parallelogram manner, as illustrated in Fig. 2. In this way, a $L$-dimensional gradient code can be formed at each pixel, and character image is decomposed into $L$ directional pattern images.

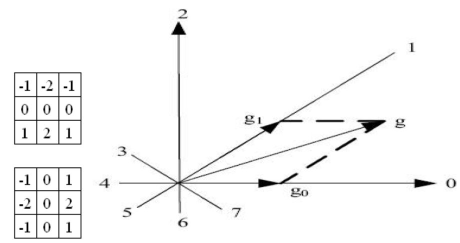


Figure. 2. Sobel Operators and decompsing of the gradient vector

Let $f_d(x,y), d = 0,\cdots,L-1$ be the directional pattern image, then we have gradient feature for the sampling point $(x_0, y_0)$ as shown in equation (10).

$$F_d(x_0,y_0) = \sum_{x=-S}^{S}\sum_{y=-S}^{S} f_d(x_0+x, y_0+y)G_1(x,y) \quad (10)$$

To extract the character feature, the character image is uniformly divided into $n\times n$ cells ( $8\times8$ in our experiments), and the center of each cell is adopted as the sampling point. Therefore we can get a 256( $4\times8\times8=256$ ) dimensions Gabor features and 512( $8\times8\times8=512$ )dimensions gradient feature respectively.

## *E. Recognition*

In recognition, we adopt a two-stage classification strategy which includes pre-classification and fine classification, and fine classification is limited within the candidate classes given by pre-classification. A minimum Euclidean distance classifier is used for each stage. At pre-classification stage, one prototype is used for each class of characters to speed up the recognition. While in fine classification, 4 prototypes for each class is formed by $k-$ means clustering method. To improve the recognition performance, the linear discriminative analysis (LDA) is used to reduce the feature dimension. In our experiments, the dimension of raw feature is reduced to 30 in pre-classification, and to 96 in fine classification.

Post-processing is another technique adopted in our system to improve the recognition performance. For each envelope, we can get a postcode string and an address string after recognition respectively. In China, postcode is a 6-digit code that corresponds to the mail address on the envelope. For example, the first three digits "510" in postcode refer to the city of GuangZhou in GuangDong province. Thus we can use this corresponding between the postcode and address to modify the recognition results. In our system, a postcode database is constructed which contains 2262 items of pairs of postcodes and their corresponding addresses for the provinces and main towns/counties in China. And the following algorithm is used to process the recognition results, where the edit distance is used for measuring the matching between the two name strings.

**Step 1**: Search for the key names of province and town/county in the recognition results by using the keywords "sheng(省)" and "shi/xian(市/县)" that mean province and town/county ,respectively. If the key names could be located, then run step 2, otherwise the algorithm terminates.

**Step 2**: If the best matched item of located town/county name in postcode database is fully matched, then modify the recognized province name and postcode according to the database. Otherwise run step 3.

**Step 3**: If the best matched item of located town/county name in postcode database is partially matched, and the corresponding postcode is fully matched, then modify the recognized province name and town/county name according to the database. Otherwise the algorithm terminates.

## IV. Experimental results

To test the performance of the proposed system, three categories of experiments are carried out on the personal computer with Microsoft Windows XP and 2.8GHz CPU. The first kind is the recognition experiments on the isolated machine printed characters to test the performance of feature extraction and recognition methods. The database used in experiments contains 4516 frequently used Chinese characters defined in GB2312-80, 62 alphanumeric characters, and 12 punctuation marks and symbols. Each character has 100 samples collected by using high-speed camera used in our system and with different printed font size and illumination. The font size of printed characters ranges from 7.5 points to 14 points.

In the experiments, three kinds of character features are tested, which are the Gabor feature based on the binary character image (GaborBin), the Gabor feature based on the gray character image (GaborGray), the gradient feature based on the gray character image (GradGray), as shown in section 3.4. The recognition strategy is adopted as shown in section 3.5. The performance of recognition error rates and processing speed on isolated machine printed characters database are summarized in Table I, where feature time is the average feature extraction time per character.

TABLE I. The performance on isolated characters database

| Feature | Feature time(ms) | Recognition time(ms) | Recognition rate(%) |
|---|---|---|---|
| GaborBin | 0.27 | 1.13 | 98.95 |
| GaborGray | 0.38 | 1.13 | 98.18 |
| GradGray | 0.45 | 1.28 | 99.49 |

From Table I, it can be seen that the Gabor feature based on the binary character image is the fastest, and the gradient feature based on the gray character image has the best recognition performance with a slower speed. Comparatively, the Gabor feature based on the gray character image has no advantages either in processing speed or in recognition rate, thus it is not used in our system.

The second category of experiments are carried out on the mail images database collected with the live mails, in order to test the overall performance of our system. The database contains 761 mail images with a total of 25,060 postcode and address characters. The ground truth for the postcode and address of each mail image is edited manually as a benchmark for recognition test. For each mail image, it is processed and recognized with the methods described in this paper, and the recognition performance is evaluated by using edit distance according to the equation (10).

$$ErrorRate = \frac{edit\ distance}{character\ number} \times 100\% \qquad (10)$$

where the edit distance refers to the edit distance between the recognition result and its ground truth, the character number refers to the character number of the corresponding ground truth.

The experimental results are summarized in Table II and III. In Table II, the recognition performance is given, where no post-processing means recognition test without using post-processing, and postcode and address refer to the recognition results for postcode and address respectively. In Table III, the CPU times for each stages of our system are given, where the preprocessing refers to the system stages that include the address block location, binarization, skew detection/correction, line segmentation and character over-segmentation, while the recognition refers to the system stages that include dynamic programming based character segmentation, feature extraction, recognition and post-processing.

TABLE II. The recognition performance on machine printed mail images database (%)

| Feature | No post-processing | | Post-processing | |
|---|---|---|---|---|
| | *Postcode* | *Address* | *Postcode* | *Address* |
| GaborBin | 97.15 | 98.35 | 99.69 | 98.41 |
| GradGray | 97.24 | 98.70 | **99.74** | **98.72** |

TABLE III. The average CPU times of our system on machine printed mail images database (ms)

| Feature | Preprocessing | Recognition | Overall System | Throughput (mails/hour) |
|---|---|---|---|---|
| GaborBin | 19.42 | 40.81 | 60.23 | 59,770 |
| GradGray | 26.49 | 54.89 | 81.38 | 44,237 |

From Table II, it can be seen that our system can reach a recognition rate of 99.74% and 98.72% for postcode and address respectively. It means that only 0.64 characters are mis-identified for an average of 50 characters address, indicating its effectiveness. In addition, recognition rate of postcode can be effectively improved with post-processing.

From Table III, it can be seen that our system can reach a processing speed of 59,770 and 44,237 mails per hour for GaborBin feature and GradGray feature respectively. This is much faster than that reported in literature, indicating its efficiency.

Finally, our system is tested on site with live mails in postal service center. A high-speed camera is used to capture the images of envelopes running on the convey device and a laser sensor is equipped to detect the mail arriving signal. The captured images are fed into our system for mail identification. The recognition results and the corresponding envelope image are saved in the database in real time. The experimental results are given in Table IV. In this experiment, the Gabor feature based on the binary character image is used, and the recognition rate is computed by checking the recognition results manually. A total of 75 envelopes representing 2470 characters of postal addresses are tested and the Throughput (mails/hour) is given by the convey device.

TABLE IV. THE PERFORMANCE OF OUR SYSTEM TESTED ON SITE

| Feature | Font Size(points) | Recognition rate (%) | Throughput (mails/hour) |
|---|---|---|---|
| GaborBin | no less than 10.5 | 98.92 | 21,000 |
| GaborBin | 7.5-9 | 94.44 | 21,000 |

From Table IV, it can be seen that, the recognition rate can reach 98.92% for envelopes with printed font size of no less than 10.5 points, and 94.44% for envelopes with printed font size from 7.5 to 9 points. The processing speed is 21,000 mails per hour. It should be noted that the processing speed in Table IV is determined by the envelopes with a maximum of 50 characters of postal address for the need of real-time processing, and the processing time consists of not only the CPU times reported in Table III but also the times for obtaining the envelopes image by high-speed camera and transferring and saving in real time the recognition results into the database located on another personal computer. In addition, the recognition performance of envelopes with font size from 7.5 to 9 points can be further improved by zooming in the lens for practical applications.

## V. CONCLUSION

Automatic postal addresses recognition is one of the most important applications of offline optical character recognition, which aims to automatic sorting of mail pieces or assigns a bar code in terms of recognized address for subsequent mail sorting, tracking and management. This paper focuses on real-time processing of the machine printed Chinese postal envelopes. By using a laser sensor to detect the envelope arriving signal, a vision-based fast postal envelope identification system for moving machine printed Chinese postal envelopes is proposed. Our system uses a high-speed camera to capture the images of envelopes running on the convey device and then recognizes the postal address and postcode on the envelopes. The experimental results show that the proposed system can achieve high-speed processing and recognition of moving envelopes with high precision. For the envelope with an average of 32.9 characters, it can be processed and recognized within 81.38 milliseconds while the character recognition rate of postal address is 98.72%.

Furthermore, our system also provides the function to store the envelope images and their recognition results into database in real time, which is very convenient for subsequent envelopes tracking and management. The experimental results with live mails on site indicate that our system can reach a speed of about 21,000 mails per hour, and the character recognition rate of postal address is as high as 98.92%. Besides, our system can be conveniently equipped on the envelope processing devices in postal service center.

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