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Recognition of the Passport by Using Fuzzy Binarization and Enhanced Fuzzy Neural Networks

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Abstract - **The judgment of forged passports plays an important role in the immigration control system, for which the automatic and accurate processing is required because of the rapid increase of travelers. So, as the preprocessing phase for the judgment of forged passports, this paper proposed the novel method for the recognition of passport based on the fuzzy binarization and the fuzzy RBF neural network newly proposed. First, for the extraction of individual codes being recognized, the paper extracts code sequence blocks including individual codes by applying the Sobel masking, the horizontal smearing and the contour tracking algorithm in turn to the passport image, binarizes the extracted blocks by using the fuzzy binarization based on the membership function of trapezoid type, and, as the last step, recovers and extracts individual codes from the binarized areas by applying the CDM masking and the vertical smearing. Next, the paper proposed the enhanced fuzzy RBF neural network that adapts the enhanced fuzzy ART network to the middle layer and applied to the recognition of individual codes. The results of the experiment for performance evaluation on the real passport images showed that the proposed method in the paper has the improved performance in the recognition of passport.**

I. Introduction

The immigration control system authorizes the immigration of travelers by means of passport inspections such as the judgment of forged passports, the search for a wanted criminal or a person disqualified for immigration, etc. The judgment of forged passports plays an important role in the immigration control system, for which the automatic and accurate processing is required because of the rapid increase of travelers. We proposed the fuzzy image binarization method and the fuzzy RBF neural network, and by using the methods, implemented the novel method for the recognition of passports required in the preprocessing phase for the judgment of forged passports.

For extracting the individual codes being recognized from the passport image, we extracted the code sequence blocks including individual codes by using the Sobel masking, the horizontal smearing and the 4-directional contour tracking, and extracted the individual codes form the code sequence blocks by using the fuzzy binarization newly proposed, the CDM masking and the vertical smearing. And in the paper the fuzzy RBF network was proposed and applied for the recognition of extracted codes, which constructs the middle layer by using the enhanced fuzzy ART network, supporting the dynamical change of vigilance parameter and the adjustment of the weight of connection between the input layer and the middle layer. The experiments for performance evaluation showed the improvement of the learning performance and the recognition rate in the proposed fuzzy RBF network.

This paper is organized as follows. Section II and III examine in detail the individual code extraction and the code recognition respectively. Section IV shows the performance evaluation and Section V finishes with conclusions.

II. Individual Code Extraction

The passport image consists of the three areas, the picture area in the top-left part, the user information area in the top-right part, and the user code area in the bottom part. We, for the recognition of passports, extract the user codes from the passport images, and recognize and digitalize the extracted codes. The proposed algorithm for the passport recognition consists of two phases, the individual code extraction phase extracting individual codes being recognized from the original image and the code recognition phase recognizing the extracted codes. This section examines the individual code extraction phase.

A. Code Sequence Block Extraction

Fig. 1 shows an example of passport images used for experiment in the paper. First, we extract the user code area, and next, extract the picture area to take the raw information from passport images.

The user code area in the bottom part of passport image has the white background and the two code rows including 44's codes. For extracting the individual codes from the passport image, first, we extract the code sequence blocks including the individual codes by using the feature that the user codes are arranged sequentially in the horizontal direction. The extraction procedure of code sequence blocks is as follows: First, the Sobel masking is applied to the original image to generate an edge image. By applying the horizontal smearing to the edge image, the adjacent edge blocks are combined into a large connected block. Successively, by applying the contour tracking to the result of smearing processing, a number of connected edge blocks are generated, and the ratio of width to height of the blocks are calculated. Last, the edge blocks of maximum ratio are selected as code sequence blocks.

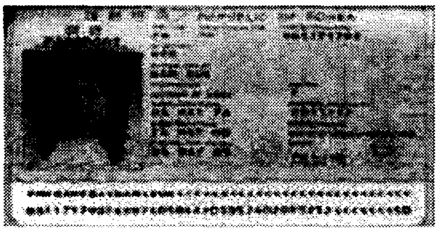


Figure 1. Example of passport image

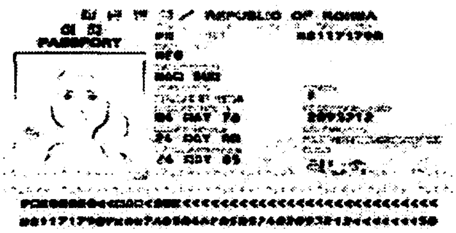


Figure 2. Result of Sobel masking in Fig. 1

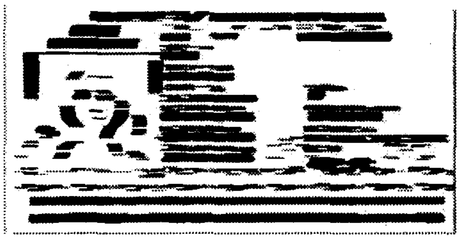


Figure 3. Result of horizontal smearing in Fig. 2

Fig. 2 shows the edge image generated by applying Sobel masking to the image in Fig. 1. Fig. 3 shows the results generated by applying horizontal smearing to the edge image. We use the 4-directional contour tracking to extract code sequence blocks from the results in Fig. 3.

The contour tracking extracts outlines of connected edge blocks by scanning and connecting the boundary pixels. The paper uses the 2x2 mask in Fig. 4 for the 4-directional contour tracking. The contour tracking scans the smeared image from left to right and from top to bottom to find the boundary pixels of edge blocks. If a boundary pixel is found, the pixel is selected as the start position of tracking. The selected pixel is placed at the x_k position of the 2x2 mask, and by examining the two pixels coming under the *a* and *b* positions and comparing with the conditions in Table 1, the next scanning direction of the mask is determined and the next boundary pixel being tracked is selected. The selected pixels coming under the x_k position are connected into the contour of the edge block. By generating the outer rectangles including contours of edge blocks and comparing the ratio of width to height of the rectangles, the code sequence blocks with the maximum ratio are extracted.

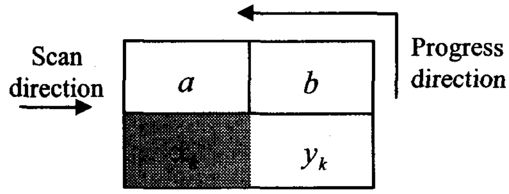


Figure 4. 2x2 mask for 4-direction contour tracking

Table 1. Progress direction of *a* and *b* by 2x2 mask

	a	*b*	x_k	y_k
Forward	1	0	*a*	*b*
Right	0	1	*b*	y_k
Right	1	1	*a*	x_k
Left	0	0	x_k	*a*

B. Individual Code Extraction

The individual codes are extracted by applying the fuzzy binarization newly proposed and the CDM (Conditional Dilation Morphology) masking to the areas corresponding to code sequence blocks in the original passport image.

We proposed the novel fuzzy binarization based on the membership function of trapezoidal shape, which supports the adaptive binarization for the images with diversely shaped objects and the various changes of intensity. Let *T* be the mean value between the maximum value(I_{Max}) and the minimum value(I_{Min}) of intensity in the original grayscale image. The interval $[I_s, I_e]$ in which the degree of membership calculated by using the membership function of trapezoidal shape becomes 1 is calculated using Eq. 1.

$$I_s = \frac{T}{3}, \quad I_e = I_s \times 2 \qquad (1)$$

So, the membership function for the interval $[I_{Min}, I_{Max}]$ is formulated as Eq. 2 and it is used to calculate the degree of membership.

$$\text{if } (I_{Min} < I \le I_s) \text{ then } \mu(I) = \frac{1}{(I_s - I_{Min})} \times (I - I_s) + 1$$
$$\text{if } (I_s < I \le I_e) \text{ then } \mu(I) = 1.0 \qquad (2)$$
$$\text{if } (I_e < I \le I_{Max}) \text{ then } \mu(I) = \frac{1}{(I_{Max} - I_e)} \times (I - I_e) + 1$$

For each pixel in the passport image, the degree of membership is calculated by using Eq. 2 and the binarization is executed by applying $\alpha - cut$ to the degree of membership. And the α value used in the $\alpha - cut$ processing is given as Eq. 3 for the adaptive binarization of passport image.

$$\alpha = (T \times 2.02 - 75)/100 \qquad (3)$$

That is, if the degree of membership of a pixel is greater than or equal to the α value, the intensity value of the pixel is set to 255. Otherwise, the intensity value is set to 0. Fig. 5 shows the proposed membership function of trapezoidal shape.

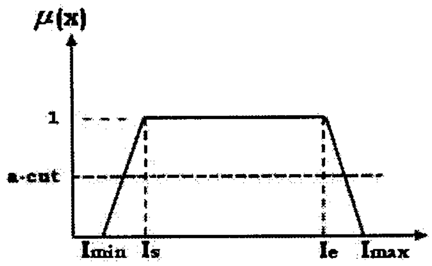


Figure 5. Fuzzy membership function of trapezoidal shape with *a-cut*

We apply the CDM(Conditional Dilation Morphology) masking to the result of binarization for the recovery of the information loss caused by the low resolution of input. The CDM masking recovers outer pixels of individual codes by executing only the dilation process without erosion and it is efficient in the images with low resolution. Last, we use the vertical smearing and the horizontal projection to extract individual codes form the result of CDM masking. By projecting the vertical smeared areas in the horizontal direction, the horizontal coordinates of individual codes are calculated.

C. Picture Area Extraction

After individual codes are extracted, we extract the picture area by using the start position of code sequence blocks and the features that the vertical edge of picture area is greater than the horizontal edge and the ratio of horizontal edge to vertical edge becomes approximately 3:4. First, we select as the candidate area the area with the same start position as code sequence blocks in horizontal and the width as long as 1/3 of the width of the original image. And because the Sobel masking makes the contour of picture more vivid by generating the thick edges, it is applied to the candidate area to extract edges. By generating the horizontal and vertical histograms in terms of the result of Sobel masking, the position of picture area is calculated based on the feature information. The proposed method using only the Sobel masking and the histogram reduces the time required for picture area extraction.

III. Recognition of Passports Using the Enhanced Fuzzy RBF Neural Network

We proposed the enhanced fuzzy RBF network which constructs the middle layer by using the enhanced fuzzy ART network for the recognition of extracted codes. In the traditional fuzzy ART network, the vigilance parameter determines inversely the allowable degree of mismatch between any input pattern and saved patterns. The large value of vigilance parameter classifies an input pattern to a new category in spite of a little mismatch between the pattern and the expected patterns and oppositely the small value may allow the classification of the input pattern to an existing cluster in spite of a much mismatch. Moreover, because many applications of image recognition based on the fuzzy ART network give the empirical value to the vigilance parameter so that the decrease of the success rate of recognition may be incurred. To correct this defect, we proposed the enhanced fuzzy ART network and applied to the middle layer in the RBF network.

The enhanced fuzzy ART network adjusts the vigilance parameter dynamically according to the homogeneity between the patterns by using Yager's intersection operator, one of fuzzy connection operators. The vigilance parameter is dynamically adjusted only in the case that the homogeneity between the saved pattern and the learning pattern is greater than or equal to the vigilance parameter. Also, the proposed fuzzy ART network adjusts the weight of connection for the learning patterns with the authorized homogeneity: Let T_{j*}^{p} and T_{j*}^{p*} be the target value of the learning pattern and the saved pattern respectively. If T_{j*}^{p} is equal to T_{j*}^{p*}, the network decreases the vigilance parameter and adjusts the weight of connection between the input layer and the middle layer. Otherwise, the network increases the vigilance parameter and selects the next winner node.

The algorithm dynamically adjusting the vigilance parameter is as follows:

$$\textit{if } \left(T_{j*}^{p} \neq T_{j*}^{p*}\right) \textit{ then}$$
$$\rho(t+1) = 1 - \wedge\left(1, \left((1-\rho(t))^{-2} + (1-\rho(t-1))^{-2}\right)^{-1/2}\right) \qquad (4)$$
$$\textit{else } \rho(t+1) = 1 - \wedge\left(1, \left((1-\rho(t))^{2} + (1-\rho(t-1))^{2}\right)^{1/2}\right)$$

where ρ is the vigilance parameter.

The authorization of homogeneity for the selected winner node is executed according to Eq. 5.

$$\frac{\|w_{ij*} \wedge x_i^p\|}{\|x_i^p\|} < \rho \qquad (5)$$

If output vector of the winner node is greater than or equal to the vigilance parameter, the homogeneity is authorized and the input pattern is classified to the same as the saved. And, in the case, the weight of connection is adjusted according to Eq. 6 to reflect the homogeneity of the input pattern to the weight.

$$w_{ij*}(t+1) = \beta \times (x_i^p \wedge w_{ij*}(t)) + (1-\beta) \times w_{ij*}(t) \qquad (6)$$

where β is the learning rate between 0 and 1.

When the weight is adjusted in the traditional fuzzy ART network, β is set to the empirical value. If the large value of β is given, the success rate of recognition goes down because the information loss of the saved patterns is caused by the increase of the number of cluster update. Oppositely, if the learning is performed with the small value of β, the information of the current learning pattern is little reflected to the saved patterns and the number of clusters increases. So, in the enhanced fuzzy ART network, the value of β is dynamically adjusted based on the difference between the homogeneity of the learning pattern to the saved pattern and the vigilance parameter. The adjustment of β is as follows:

$$\beta = \frac{\dfrac{\|w_{ij*} \wedge x_i^p\|}{\|x_i^p\|} - \rho}{(1-\rho)} \qquad (7)$$

IV. Performance Evaluation

For performance evaluation, we implemented the proposed algorithm and experimented on the IBM-compatible PC with Intel Pentium-IV 2GHz CPU and 256MB RAM. And the 20's passport images of 600x437 pixel size were used in the experiments.

Fig. 6 (a) shows the result of individual code extraction on the passport image in Fig. 1, and Fig. 6 (b) shows the result of picture area extraction. Fig. 7 shows the individual codes finally extracted by using fuzzy binarization and CDM masking.

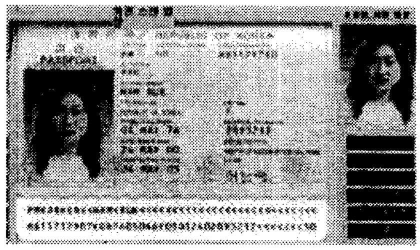
Table 2 represents the number of code sequence blocks and individual codes extracted from 20's passport images.

Table 2. Number of extraction for code sequence blocks and individual codes

	Code Sequence Blocks	Individual Codes
The number of extraction (success/target)	40 / 40	1760 / 1760

The extracted individual codes divides into 1140's alphabetic codes and 620's numeric codes. In the paper alphabetic codes and numeric ones were used separately in the learning and recognition experiments. To evaluate the learning performance of the enhanced fuzzy ART network, this paper compared the number of clusters generated by the traditional fuzzy ART network and the enhanced fuzzy ART network in the learning experiments on individual codes. Table 3 shows the result of the learning experiments. In the experiments, the vigilance parameters for the traditional fuzzy ART network were set to 0.9 and 0.85 for the alphabetic and the numeric codes respectively, and for the enhanced fuzzy ART network, the initial values of the vigilance parameter were set to 0.9 and 0.85 respectively.

(a) Example of individual code extraction



(b) Example of picture extraction

Figure 6. Example of individual code and picture extraction

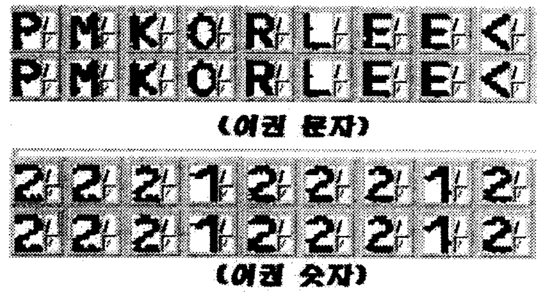


Figure 7. Example of codes extracted by fuzzy binarization and CDM masking

Table 3. Comparison of the number of clusters between the fuzzy ART and the proposed fuzzy ART network

		Number of clusters / Number of patterns
Alphabetic Codes	Proposed Fuzzy ART	48 / 1140
	Fuzzy ART	303 / 1140
Numeric Codes	Proposed Fuzzy ART	14 / 620
	Fuzzy ART	142 / 620

As known in Table 3, the number of clusters in the enhanced fuzzy ART network was much lower than in the traditional fuzzy ART network, so we may know that the enhanced fuzzy ART network refines the classification of the homogenous patterns properly.

Table 4 shows the results of the experiment that the enhanced fuzzy RBF network was applied to 20's passport images for the passport recognition. In the experiment, the initial values of the vigilance parameter used for the creation and update of the nodes in the middle layer were set to 0.9 and 0.85 for the alphabetic and the numeric codes respectively. As known in Table 4, the proposed fuzzy RBF network recognized successively all of the individual codes extracted.

Table 4. Result of learning and recognition by the proposed fuzzy RBF network

	The number of nodes in middle layer	The number of Epoch	The number of recognition
Alphabetic Codes	48 / 1140	4068	1140 /1140
Numeric Codes	14 /620	1527	620 / 620

Fig. 8 shows the dynamical change of the vigilance parameter in terms of the update progress of the parameter in the clustering of the middle layer.

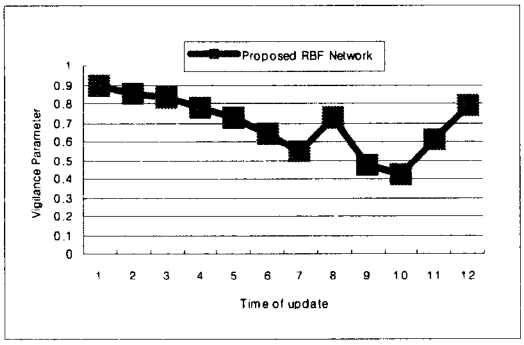


Figure 8. Dynamical change of vigilance parameter

In conclusion, the experiment for performance evaluation shows that the proposed fuzzy RBF network improves the learning performance and the success rate of recognition by supporting the dynamical change of the vigilance parameter and the adjustment of the weight of connection between the input layer and the middle layer.

V. Conclusions

The judgment of forged passports plays an important role in the immigration control system, for which the automatic and accurate processing is required because of the rapid increase of travelers. Fist, we proposed the fuzzy image binarization method and the fuzzy RBF neural network, and by using the proposed methods, implemented the novel method for the recognition of passports.

We, in the individual code extraction phase, extracted the code sequence blocks including individual codes by using the Sobel masking, the horizontal smearing and the 4-directional contour tracking based on the 2x2 mask, and extracted the individual codes form the code sequence blocks by using the proposed fuzzy binarization, the CDM masking and the vertical smearing. And in the paper the enhanced fuzzy RBF network was proposed and applied in the code recognition phase, which constructs the middle layer by using the enhanced fuzzy ART network, supporting the dynamical change of the vigilance parameter and the adjustment of the weight of connection between the input layer and the middle layer.

In the experiments for performance evaluation using 20's passport images, the number of clusters created at the learning process of the enhanced fuzzy ART network was much lower than the traditional fuzzy ART network, which means that it is efficient to use the enhanced fuzzy ART network in the construction of middle layer in the fuzzy RBF network. And the proposed fuzzy RBF network recognized all of the individual codes extracted from the passport images.

As the future works, the face authorization method is required for the precise judgment of forged passports and the research for the face authorization is needed

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