A Passport Recognition and Face Verification Using Enhanced Fuzzy Neural Network and PCA Algorithm

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Abstract. In this paper, passport recognition and face verification methods which can automatically recognize passport codes and discriminate forgery passports to improve efficiency and systematic control of immigration management are proposed. Adjusting the slant is very important for recognition of characters and face verification since slanted passport images can bring various unwanted effects to the recognition of individual codes and faces. The angle adjustment can be conducted by using the slant of the straight and horizontal line that connects the center of thickness between left and right parts of the string. Extracting passport codes is done by Sobel operator, horizontal smearing, and 8-neighbornood contour tracking algorithm. The proposed RBF network is applied to the middle layer of RBF network by using the fuzzy logic connection operator and proposing the enhanced fuzzy ART algorithm that dynamically controls the vigilance parameter. After several tests using a forged passport and the passport with slanted images, the proposed method was proven to be effective in recognizing passport codes and verifying facial images.

1 Introduction

Because of globalization and the improvement of transportation, the number of people that arrive from and depart to different countries from airports has increased. The clerk of immigration control currently uses his/her bare eye to verify the passport. The purpose of immigration control is to find forgery, criminal, illegal immigrants, or someone prohibited from departing the country. A passport has information about the owner's identification photograph, nationality, name, social security number, gender, passport number, and so on.

It is difficult to use only bare eyes to distinguish and control the immigration process [1]. Time will be delayed, and due to obscure and unsure methods, accurate search of people who shouldn't be allowed in the country will not be possible. Therefore, this paper shows how to extract a string area of codes by applying Sobel operator, horizontal smearing, and 8-neighborhood contour tracking algorithm. The extracted string area becomes binary by applying a repeating binary

I. King et al. (Eds.): ICONIP 2006, Part II, LNCS 4233, pp. 167–176, 2006.

method, which is applied with a CDM (Conditional Dilation Morphology) mask in order to recover the characters of an individual code [2],[3].

In order to extract individual codes from the string area to which CDM mask is applied, the individual code is extracted by 8-neighborhood contour tracking algorithm [4]. The remainder of this study is organized as follows. Section 2 presents the code extraction and slant compensation in detail. Passport recognition and forgery detection algorithms are introduced in Section 3 and 4, respectively. The experimental results are discussed in Section 5. Conclusions are drawn in Section 6.

2 Passport Code Extraction and Slant Compensation

The user information is represented in one code that is placed in the bottom of the passport. The passport code must be extracted in order to recognize the user information. In this paper, real passports that are currently in use are used to extract code areas that consist of 44 characters stands in two rows.

2.1 Code Extraction

The edge is detected by applying the Sobel mask to an original image of the passport, and horizontal smearing is applied to the image in which the Sobel mask has been applied. The method for extracting the string area of codes by applying the 8-neighborhood contour tracking algorithm to the horizontally smeared images is as following.

P_i^r and P_i^c are the vertical and horizontal pixels of the string areas of the extracted code, P_i^{r+1} and P_i^{c+1} are the next progressing vertical and horizontal pixels, respectively. P_s^r and P_s^c are vertical and horizontal pixels of the first contour tracking mask, respectively.

Step 1. Initialize with Eq. (1) in order to apply 8-neighbornood contour tracking algorithm to the string code area, and find the pixel by applying progressing mask as shown in Fig. 1.

$$P_i^{r-1} = P_i^r, \quad P_i^{c-1} = P_i^c \tag{1}$$

Step 2. When a black pixel is found after applying the progressing mask in the current pixel, calculate the value of P_i^r and P_i^c as shown in Eq. (2).

$$P_i^r = \sum_{i=0}^{7} P_i^{r+1}, \;\; P_i^c = \sum_{i=0}^{7} P_i^{c+1} \tag{2}$$

Step 3. For the 8 progressing masks, apply Eq. (3) to decide the next progressing mask.

$$\text{If } P_i^r = P_i^{r+1} \text{ and } P_i^c = P_i^{c+1} \text{ then rotates counter-clockwise} \tag{3}$$

Step 4. Stop if P_i^r and P_i^c return back to P_s^r and P_s^c or go back to the Step 1 and repeat. If $|P_i^r - P_s^r| \leq 1$ and $|P_i^c - P_s^c| \leq 1$ then Break, else go back to the Step 1.

6	5	4
7		3
0	1	2

EE

7	6	5
0		4
1	2	3

SE

0	7	6
1		5
2	3	4

SS

1	0	7
2		6
3	4	5

SW

2	1	0
3		7
4	5	6

WW

3	2	1
4		0
5	8	7

NW

4	3	2
5		1
6	7	0

NN

5	4	3
6		2
7	0	1

NE

Fig. 1. 8-neighborhood contour tracking process mask

2.2 Slant Compensation of Image

Since passport images can be tilted during the scan, "image slant compensation" is very important for face verification. If there is no slant during the extracting of strings of passport codes, extracting strings by selecting two areas that form maximum section by horizontal projection is possible. However, if slanting exists, this method is not useful. Skew compensation is applied by selecting the longer of two extracted strings, and then using the straight line that connects the center of the string's thickness of the left and right sides and the slant of the horizontal line of that string. The extraction of code area and the image tilt compensation of the proposed method are shown in Fig. 2.

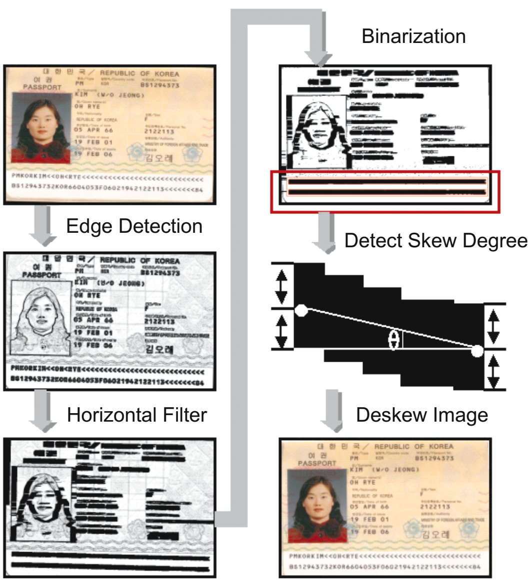

Fig. 2. Code character detection and skew compensation

2.3 Image Enhancement and Extraction of Individual Codes

CDM mask shown in Fig. 3 is used in order to transform the extracted string area to binary information, and to restore the characters of the individual code of the binarized string area.

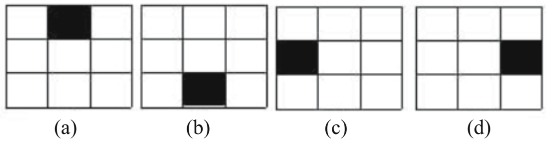

Fig. 3. CDM mask

The first step, Fig. 3(a), reconstructs bounding box's top horizontal outermost portion if the mask reach to character information into interior for horizontal direction by top-down method. The second step reconstructs left vertical elements by using a left-right method. The third step reconstructs horizontal elements of character from the bottom by using a bottom-up method. The fourth step reconstructs vertical elements of character from the right by using a right-left method.

Because the number of pixels that CDM mask is applied to vertical elements among the outermost pixels in a pixel per 3×3 mask, the image scanned in low restoration, 150 dpi, is available effectively. Fig. 4 shows the process that converges for up, down, right, and left directions in application form of CDM mask. After applying CDM Mask, 88 individual codes are extracted by using 8-neighborhood contour tracking algorithm. Fig. 5 shows the result of extracting individual codes with 8-neighborhood contour tracking algorithm.

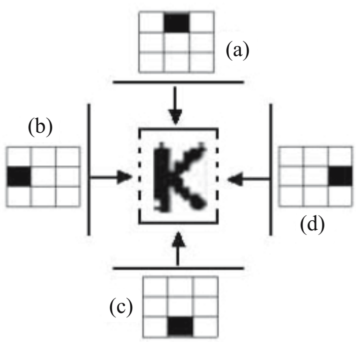

Fig. 4. Application of CDM mask

3 Passport Recognition by the Enhanced Fuzzy ART Based RBF Network

The RBF (Radial Basis Function) network based on enhanced fuzzy ART (Adaptive Resonance Theory) is applied for passport recognition. The proposed fuzzy

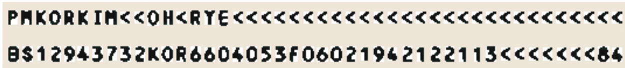

Fig. 5. Extraction result for individual character

RBF network is divided into two stages: a fuzzy logic connection operator to control vigilance parameters and Delta-bar-Delta to control the learning rate. Fuzzy ART is a self-learning algorithm that combines fuzzy logic and the ART learning model [5]. The vigilance parameter determines the allowable degree of mismatch between any input pattern and stored pattern [6]. Yager's intersection operator is defined as the following [7].

$$\mu(x_i) = 1 - Min\left[1,\ \{(1-X_1)^p + \ \cdots \ + (1-X_n)^p\}^{1/p}\right] \tag{4}$$

Let T^p and T^{p^*} be the target values of the learning pattern and the winner node, respectively. The equation to apply Yager's intersection operator and dynamically control vigilance parameters is as Eq. (5).

$$\begin{aligned}&\text{If}\quad T^p = T^{p^*}\ \text{then}\\ &\rho_{j^*}(t+1) = 1 - \wedge\left[1,\ \left\{(1-\rho_{j^*}(t))^2 + \left(1-\rho_{j^*}(t-1)\right)^2\right\}^{1/2}\right]\end{aligned} \tag{5}$$

The equation for controlling weight W from the conventional fuzzy ART algorithm is as following.

$$W(t+1) = \beta\,(X \wedge W(t)) + (1-\beta)\ W(t-1) \tag{6}$$

The recognition rate decreases if the value of β is too large in the conventional fuzzy ART [8]. Therefore, the learning parameter β is controlled dynamically as shown in Eq. (7) by considering actual distortion between stored patterns and learning patterns.

$$\beta = \frac{1}{1-\rho} \times \left(\frac{\|w_{j^*i} \wedge x_i\|}{\|x_i\|} - \rho\right) \tag{7}$$

Delta learning method is applied to update parameters between the middle and output layers. The output vector in the output layer can be calculated by Eq. (8), and normalized by the sigmoid function in Eq. (9).

$$O_k = \left(\sum_{j=1}^{M} w_{kj} \times O_j\right) \tag{8}$$

$$f(x) = \frac{1}{1+e^{-x}} \tag{9}$$

The equations to get the error value and error signal by comparing the normalized output vector and target vector is as following.

$$E = \frac{1}{2}(T_k^p - O_k)^2 \tag{10}$$

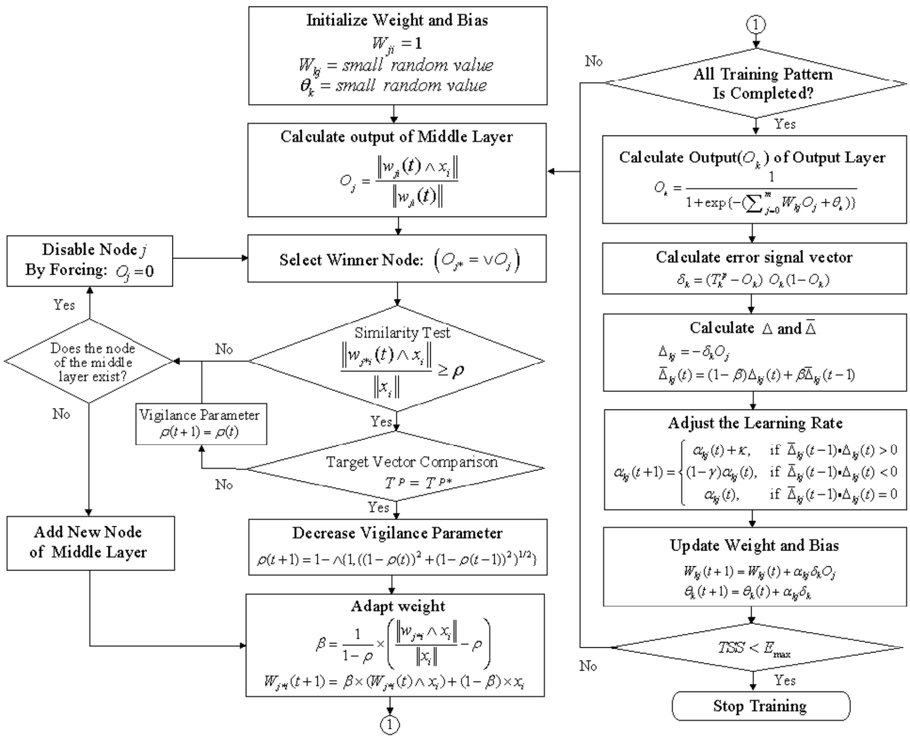

Fig. 6. Schematic diagram of the RBF network based on enhanced fuzzy ART

$$\delta_k = (T_k^p - O_k)\, O_k(1 - O_k) \tag{11}$$

After getting Delta-bar-Delta using Eq. (12) for the dynamic adjustment of the learning rate, the learning rate is dynamically adjusted by Eq. (13).

$$\begin{aligned} \Delta_{kj} &= -\delta_k O_j \\ \overline{\Delta}_{kj} &= (1-\beta)\Delta_{kj}(t) + \beta\overline{\Delta}_{kj}(t-1) \end{aligned} \tag{12}$$

$$\alpha_{kj}(t+1) = \begin{cases} \alpha_{kj}(t) + \kappa, & \text{if } \overline{\Delta}_{kj}(t-1)\cdot\Delta_{kj}(t) > 0 \\ (1-\gamma)\alpha_{kj}(t), & \text{if } \overline{\Delta}_{kj}(t-1)\cdot\Delta_{kj}(t) < 0 \\ \alpha_{kj}(t), & \text{if } \overline{\Delta}_{kj}(t-1)\cdot\Delta_{kj}(t) = 0 \end{cases} \tag{13}$$

The equations for weight and bias are updated as in Eq. (14) and Eq. (15). The schematic diagram of the proposed RBF network based on enhanced fuzzy ART is shown in Fig. 6.

$$w_{kj}(t+1) = w_{kj}(t) + \alpha_{kj}\delta_k O_j \tag{14}$$

$$\theta_k(t+1) = \theta_k(t) + \alpha_{kj}\delta_k \tag{15}$$

4 Forgery Detection by Face Verification

The recognized passport code information is used to obtain the feature vectors of facial image that is acquired by PCA algorithm from the database.

4.1 PCA

PCA finds the collection of certain normalized orthogonal axis that indicates to each direction of maximum covariance for input data. The learning method using PCA is as following [9]. The two-dimensional image can be presented by a vector, and the k number of learned image vectors can be presented by $X = \left[x^1|x^2|x^3|\cdots|x^k\right]$'s rows. An image's average vector can be acquired by Eq. (16) and the difference between the one-dimensional image vector and average image vector can be acquired by Eq. (17).

$$m = \frac{1}{k}\sum_{j=1}^{k} x^i \tag{16}$$

$$\overline{x}^i = x^i - m \tag{17}$$

By using the k number of $\overline{x}^i$ vectors which is the result of Eq. (17), the $\overline{X} = \left[\overline{x}^1|\overline{x}^2|\overline{x}^3|\cdots|\overline{x}^k\right]$ row can be acquired. $\overline{X}$ row can be used to obtain the covariance matrix by using Eq. (18).

$$\Omega = \overline{X}\,\overline{X}^T \tag{18}$$

The method for representing the studied images in PCA data is as following. After obtaining the $V = \left[v^1|v^2|v^3|\cdots|v^k\right]$ by using eigenvectors that are acquired through the covariance matrix, obtain the property vectors of the studied images using Eq. (19).

$$\tilde{x}^i = V^T \bar{x}^i \tag{19}$$

For face recognition using PCA, first the target image is subtracted from the average image to get the $\overline{y}^i$ image. Eq. (20) shows how the $\overline{y}^i$ image is acquired. Then, using the transposed matrix of the eigenvector, the feature vector of the target image is obtained as in Eq. (21).

$$\overline{y}^i = y^i - m \tag{20}$$

$$\widetilde{y}^i = V^T \overline{y}^i \tag{21}$$

4.2 Extraction of Facial Area of Passport Picture

The position of the picture in the passport is in between 1/5 and 4/5 of the vertical length and 1/3 of the horizontal width of the passport image based on the top left of the extracted code string. From the center of 2/3 of the width in the candidate area, we extract 50 pixels of the width, 130 pixels of the length, from the left and right. The final extracted region is used the face area. The method for extracting a passport picture is shown in Fig. 7.

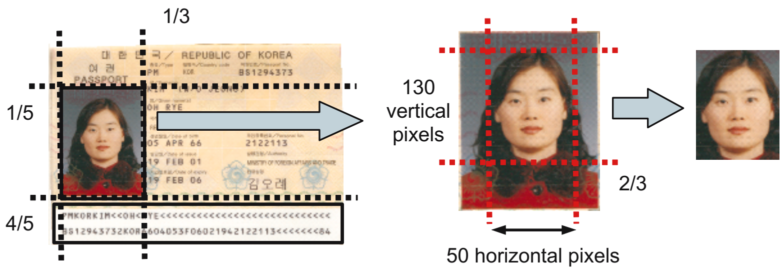

Fig. 7. Face area detection of passport picture

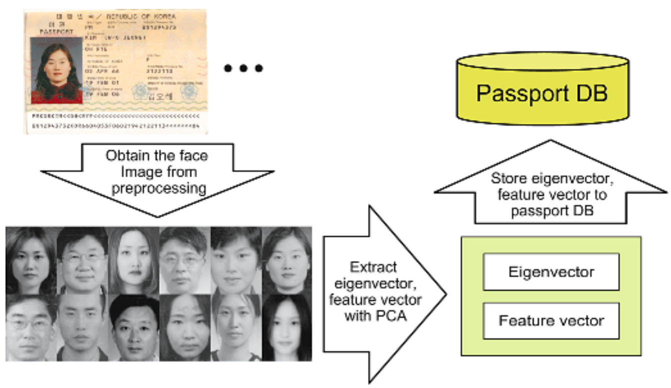

Fig. 8. Database construction for face information

4.3 Database Construction for Face Information

First, acquire images of facial area by the process of extracting facial areas from several passports. Study the acquired facial images using the PCA algorithm, and add the unique vector and feature vector of the learned facial images to the database. By using the information of the unique vector and feature vector, the verification of facial similarity is possible. The process of database construction of facial information is shown in Fig. 8.

4.4 Face Authentication

After acquiring the unique vector and feature vector from both the database and actual passport, face authentication of a passport can be done by calculating the feature vector of facial images by using Eq. (17) and (18).

The similarity of feature vectors between the calculated facial image and the database can be calculated using Eq. (19). If the similarity rate exceeds a certain critical value, the passport is valid; if not, it is possible to assume that the passport is forged.

Table 1. Nodes of created middle layer

Learning Algorithm	Pattern	Nodes of created middle layer
RBF network based	Numeric	85
enhanced fuzzy ART	Character	162

Table 2. Recognition rate of passport

	Character	Numeric	Recognition rate
Normal	1045/1116	2034/2052	97%
Slant compensation	1116/1116	2052/2052	100%

5 Analysis of Experiment and Result

The experiment was conducted by VC++ 6.0 on an Intel Pentium-IV 2GHz CPU. Twelve 600×437 sized images from the passport which are scanned by HP ScanJet 4200C, twelve images with facial forgery, and twelve images with fake picture were used for this experiment.

The result of extracting individual characters from a passport image is shown in Fig. 5. The 72 string areas from 36 passport images are all extracted, and both 2052 individual code characters and 1116 individual numbers are all extracted. 100 number codes and 260 character codes among the extracted 3168 passport codes are trained by applying the enhanced fuzzy ART based RBF Network algorithm. The parameter setting of the enhanced fuzzy ART based RBF network is as follows: $\alpha(0.7)$ is learning rate, $\mu(0.9)$ is momentum, and $\kappa(0.00005)$, $\gamma(0.001)$, $\beta(0.9)$ are delta-bar-delta constants. The number of nodes in the middle layer to which the enhanced fuzzy ART based RBF Network algorithm is applied is shown in Table 1.

The recognition rate of the 36 passport images made for the efficiency test is shown in Table 2. The passport images are recognized 97% of the time by mere scanning, but they are recognized 100% of the time by scanning using image-slant compensation.

12 original passports, 12 passports with fake pictures, and 12 passports with forged facial areas were used. The facial verification similarity was set at 0.8 for the experiment. The result is shown in Table 3. The passports with fake pictures and forged facial areas are distinguished as counterfeit. On the other hand, the original passports passed safely. Therefore, PCA algorithm is proven to be effective for face verification.

Table 3. Image verification of passport face

	Original passport	Face forgery	Picture forgery
Detection of forgery	0/12	12/12	12/12
Pass	12/12	0/12	0/12

6 Conclusion

The string codes are restored by applying CDM mask to the binary string area, and individual codes are extracted by 8-neighborhood contour tracking algorithm. The enhanced fuzzy ART based RBF network is applied to prevent different patterns from being classified as the same cluster or same patterns from being classified as different clusters. All twenty-four forged passports are detected during the face verification experiment by PCA algorithm that measures the similarity of facial feature vector. The experimental results show that the proposed facial recognition algorithm is effective.

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