Passport Recognition Using Enhanced ART2-based RBF Neural Networks

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Summary
The judgment of forged passports plays an important role in the immigration control system and requires the automatic recognition of passports as the pre-phase processing. This paper, for the recognition of passports, proposed a novel method using the enhanced RBF network based on ART2. The proposed method extracts code sequence blocks and individual codes by applying the Sobel masking, the smearing and the contour tracking algorithms in turn to passport images. The enhanced RBF network was proposed and used for the recognition of individual codes that applies the ART2 algorithm to the learning structure of the middle layer. The experiment results showed that the proposed method has superior in performance in the recognition of passport.

Key words:
recognition of passports , enhanced RBF network , contour tracking , ART2

1. Introduction

Due to the globalization and the advance of travel vehicles, the number of passengers of overseas travel is gradually increasing. The current immigration control system carries out manually the passport inspection and requires a long time for immigration, putting passengers to inconvenience. And the automatic passport inspection requires the precise processing so as to execute the critical functions such as the judgment of forged passports, the search for a wanted criminal or a person disqualified for immigration, etc[1]. This paper, for the precise passport inspection, proposed a novel passport recognition method that supports the code extraction using smearing method and contour tracking algorithm and the code recognition using the enhanced RBF network based on ART2.
As the edge extraction methods, the various methods such as Sobel operator, Roberts and Laplacian differential operators etc. are used[2]. The Roberts and the Laplacian differential operators don't process robustly noises and needs the preprocessing like the Gaussian smoothness, incurring overhead in the processing time. But the operators supports the high precision enough to extract edges with thickness of one pixel[3]. The Sobel operator uses the first-order differential values, so that it is robust to noises and requires small processing time[4]. So, this paper extracts edges from passport images by using the 3x3 Sobel masking rather than the Sobel operator based on partial differential operation. And this paper applies the smearing method[5,6] and the 4-directional contour tracking algorithm to the edge image for extracting individual codes being recognized: code sequence blocks are extracted by applying the horizontal smearing and the 4-directional contour tracking algorithm to the output of 3x3 Sobel masking, and individual codes are extracted by applying the vertical smearing to code sequence blocks.
This paper proposed the enhanced RBF(Radial Basis Function) network that, for the effective learning of new input patterns, carries out two step learning based on ART2 algorithm: the competitive learning between input layer and middle layer and the supervised learning between middle layer and output layer. And the enhanced RBF network was used to recognize individual codes extracted from passport images. The experiments for performance evaluation showed that the enhanced RBF network recognizes successfully individual codes of passports.
This paper is organized as follows: Section 2 and 3 examine in detail the individual code extraction and the code recognition respectively. Section 4 shows the results of performance evaluation and Section 5 finishes with conclusions.

2. Extraction of Code Blocks and Individual Codes

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. This paper, for the recognition of passports, extracts the user codes from the passport images, and recognizes and digitalizes the extracted codes. The proposed algorithm for passport recognition consists of two phases as shown in Fig. 1: the individual code extraction phase extracting individual codes being recognized from the passport image and the code recognition phase recognizing the

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extracted codes. This section examines the individual code extraction phase.

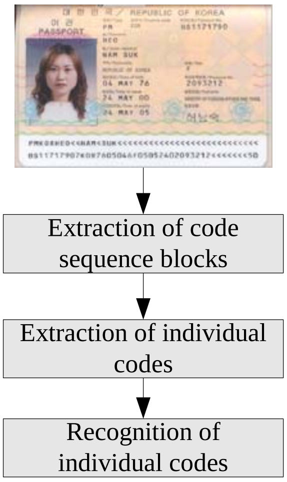

Fig. 1. Structure of the proposed algorithm for passport recognition

Fig. 2 shows an example of passport image used for experiment in this paper. The user code area has the white background and the two code rows including 44 codes at the bottom part of passport image. For extracting the individual codes from the passport image, first, this paper extracts the code sequence blocks including the individual codes by using the feature that the user codes are arranged sequentially in the horizontal direction.

Fig. 2. An example of passport image

The extraction procedure of code sequence blocks is as follows: First, the 3x3 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.

Fig. 3 shows the 3x3 Sobel mask used for the edge extraction in this paper. Fig. 4 shows the edge image generated by applying the Sobel masking to the image in Fig. 2. Fig. 5 shows the results generated by applying the horizontal smearing to the edge image.

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Fig. 3. 3x3 Sobel Mask

This paper uses the 4-directional contour tracking to extract code sequence blocks from the results in Fig. 5. The contour tracking extracts outlines of connected edge blocks by scanning and connecting the boundary pixels[7,8].

The paper uses the 2x2 mask shown in Fig. 6 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.

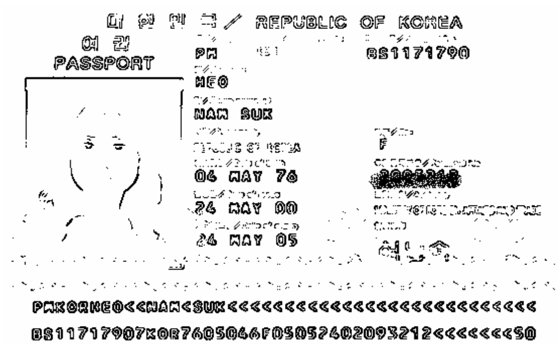

Fig. 4. Result of 3x3 Sobel masking in Fig 2

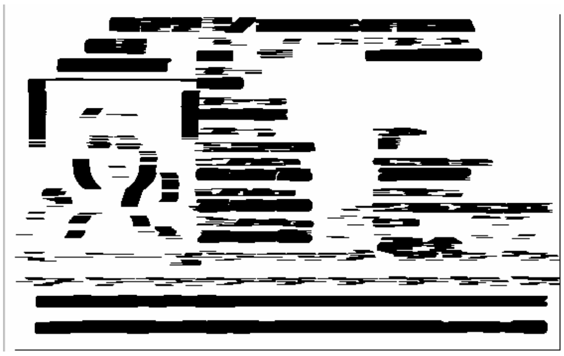

Fig. 5. Result of horizontal smearing in Fig. 4

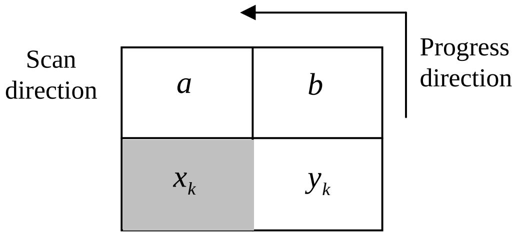

Fig. 6. 2x2 mask for 4-direction contour tracking

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

For the extraction of individual codes from code sequence blocks, this paper applies the vertical smearing to the blocks and separates each code using the vertical coordinates of vertically smeared edge sub-blocks. And using the horizontal coordinates, the size of each code is determined. The sizes of extracted codes are normalized for the code recognition using the enhanced RBF network.

3. Recognition of Passport Codes using the Enhanced RBF Network

The RBF(Radial Basis Function) network is a feed-forward neural network that consists of three layers, input layer, middle layer and output layer. In the RBF network, because the operations required between layers are different, learning algorithms between layers can be mutually different. So, the optimum organization between layers can be separately constructed[9]. Approaches to the composition of layers in the RBF network are classified to three types: The first type is the 'fixed centers selected at random' which selects nodes of the middle layer randomly from the learning data set. The second is the 'self-organized selection of centers' that decides the middle layer according to the form of self-organization and applies the supervised learning to the output layer. The last one is the 'supervised selection of centers' that uses the supervised learning for the middle layer and the output layer.

The middle layer of the RBF network executes the clustering operation, classifying input vector set to clusters including only homogeneous vectors. The measurement of homogeneity in clusters is the distance between vectors in clusters. And the classification of an input vector to a cluster means that the distances between the input vector and each vector in the cluster are shorter than or equal to the fixed radius. But, the use of a fixed radius in clustering causes wrong classifications. Therefore the selection of the organization for middle layer determines the overall efficiency of the RBF network[10].

When the learning on a series of patterns is accomplished in the RBF network, the connection weights are fixed to particular values. If a new type of pattern is given to the RBF network for learning, the learning of the new pattern has an influence on all connection weights already determined and the overall learning in the network is newly required, incurring great overhead in the processing time for learning. And in the RBF network, the learning of new patterns not learned previously is apt to classify the patterns to the cluster including similar patterns already learned. So, by using the ART2 algorithm[11], this paper enhanced the RBF network to classify a new pattern to a new cluster, having no influence on existing clusters. The enhanced RBF network based on ART2 algorithm carries out the two-step learning: the first step of learning is the competitive learning between input layer and middle layer, and the second step is the supervised learning between middle layer and output layer. Fig. 7 shows the overall procedure of learning in the enhanced RBF network.

In the enhanced RBF network, the output vector of middle layer is calculated by Eq.(1), indicating the error between the input pattern and clusters. And, the node with minimum output vector is selected as winner node like Eq.(2).

$$O_j = \frac{1}{N} \sum_{i=0}^{N-1} \left(\left| x_i - w_{ji}(t) \right| \right) \tag{1}$$

$$O_j^* = \wedge \{ O_j \} \tag{2}$$

where $\wedge$ is the function calculating the minimum value, and w_{ji} is the connection weight between input layer and middle layer. And the similarity test for the selected winner node is like Eq.(3).

$$O_j^* \prec \rho \tag{3}$$

where ρ is the vigilance parameter given in the proposed network.

If the output vector of winner node is less than the vigilance parameter, the input pattern is classified as the same pattern; otherwise it is classified as the different pattern. In the former case, the connection weight is modified to reflect the similar property of input pattern to the weight. The adjustment of connection weight is like Eq.(4).

$$w_{j^*i}(t+1) = \frac{w_{j^*i}(t) \times u_n + x_i}{u_n + 1} \tag{4}$$

where u_n is the number of updated patterns in the cluster corresponding to the winner node.

4. Performance Evaluation

For performance evaluation, this paper implemented the proposed passport recognition system by using C++ Builder tool and experimented on the IBM-compatible PC with Intel Pentium-III 550Mhz CPU and 128MB RAM. In the experiment, 30 passport images with 600x437 pixel size were used.

Fig. 8 shows code sequence blocks and individual codes extracted from Fig.2 by the proposed extraction method. And Table 2 shows the total number of code sequence blocks and individual codes extracted from 30 experiment images.

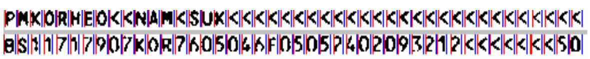

Fig. 8. Extraction result of code sequence block and individual codes

Table 2. Experiment result of the proposed extraction method

Object	Number of objects extracted / Number of failure
Code Sequence Block	60 / 0
Individual Code	2640 / 0

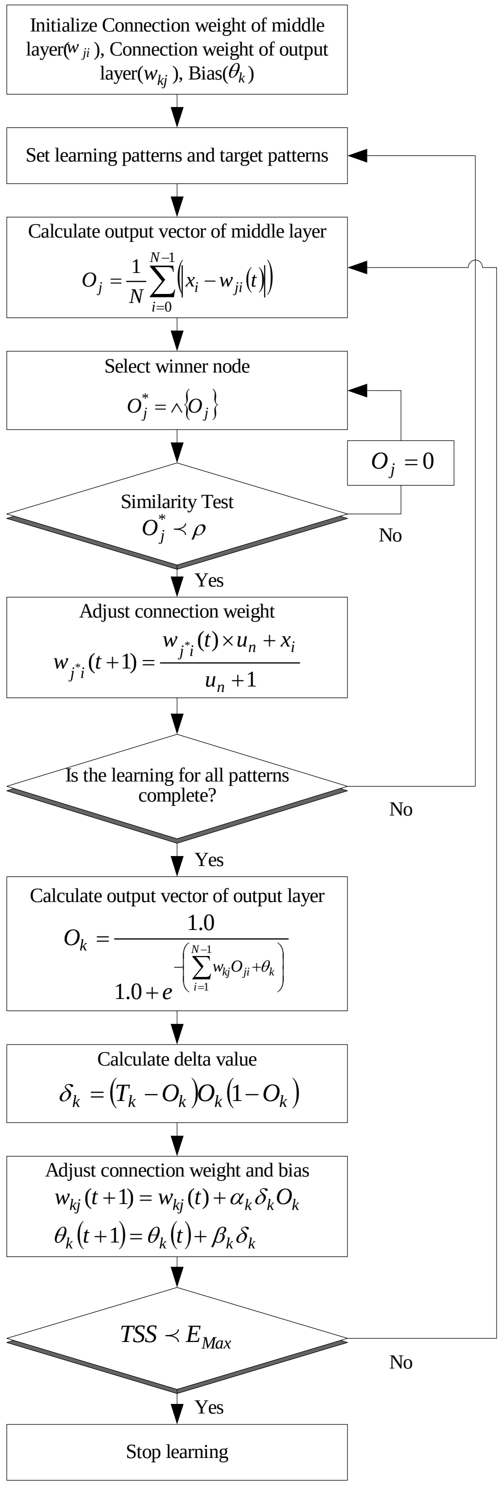

Fig. 7. Learning structure of the enhanced RBF network

Table 3 shows the result of learning experiment in the enhanced RBF network using 620 individual user codes extracted from 15 passport images. In the learning experiment, when the vigilance parameter was set to 0.2, the enhanced RBF network showed the optimal learning performance that similar patterns are not classified to different clusters in the middle layer and the number of nodes of middle layer is increasing no more.

Table 3. Result of learning experiment in the enhanced RBF network

	Number of nodes created in the middle layer	Number of Epoch
Enhanced RBF network based on ART2	217	4832

This paper divided 30 passport images to two groups: 15 images used in learning and 15 images not used in learning. To evaluate the recognition performance, the enhanced RBF network was applied to each group individually. Table 4 shows the result of recognition experiment on each group. The enhanced RBF network recognized all individual codes extracted from 30 passport images.

Table 4. Result of recognition experiment in the enhanced RBF network

	Image group used in learning	Image group not used in learning
Number of success/ Number of failure	620 / 0	615 / 0

5. Conclusions

The current immigration control system carries out manually the passport inspection and requires a long time for immigration, putting passengers to inconvenience. And the automatic passport inspection requires the precise processing so as to execute the critical functions such as the judgment of forged passports, the search for a wanted criminal or a person disqualified for immigration, etc. So, this paper, for the precise passport inspection, proposed a novel passport recognition method that supports the code extraction using smearing method and contour tracking algorithm and the code recognition using the enhanced RBF network based on ART2.

This paper, first of all, extracted the code sequence blocks including only user code strings by applying the 3x3 Sobel masking, the horizontal smearing and the 4-directional contour tracking algorithm sequentially to passport images. Next, by applying the vertical smearing to code sequence blocks, individual codes being recognized were extracted.

This paper proposed the enhanced RBF(Radial Basis Function) network that, for the effective learning of new input patterns, carries out two step learning based on ART2 algorithm: the competitive learning between input layer and middle layer and the supervised learning between middle layer and output layer. And the enhanced RBF network was used to recognize individual codes.

The experiment for performance evaluation was executed on 30 passport images and the experiment results showed that the proposed code extraction method extracts all identification codes from passport images with no failure and the enhanced RBF network recognizes successfully all individual codes.

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

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