Recognition of Passports using CDM Masking and ART2-based Hybrid Network

Kwang-Baek Kim, Jae-Hyun Cho and Young Woon Woo, *Members, KIMICS*

Abstract— This paper proposes a novel method for the recognition of passports based on the CDM(Conditional Dilation Morphology) masking and the ART2-based RBF neural networks. For the extraction of individual codes for recognizing, this paper targets code sequence blocks including individual codes by applying Sobel masking, horizontal smearing and a contour tracking algorithm on the passport image. Individual codes are recovered and extracted from the binarized areas by applying CDM masking and vertical smearing. This paper also proposes an ART2-based hybrid network that adapts the ART2 network for the middle layer. This network is applied to the recognition of individual codes. The experiment results showed that the proposed method has superior in performance in the recognition of passport.

Index Terms— Passports, CDM Masking, ART2-based RBF Hybrid Network, Horizontal Smearing, Contour Tracking Algorithm.

I. INTRODUCTION

The immigration control system authorizes the immigration of travelers by means of passport inspections, which includes the determination of forged passports, the search for a wanted criminal or a person disqualified for immigration, etc. The determination of forged passports plays an important role in the immigration control system, for which automatic and accurate processing is required because of the rapid increase of travelers.

For extracting the individual codes from the passport image for recognizing, we extract the code sequence blocks including individual codes using Sobel masking, horizontal smearing and 4-directional contour tracking[1]. Then we extract the individual codes from the code sequence blocks using a CDM masking[2] and vertical smearing. 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 hybrid network based on ART2.

The experiments for performance evaluation of the ART2-based hybrid network showed considerable improvement in learning performance and recognition rate.

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. This paper, for the recognition of passports, extracts the user codes from the passport images, and recognizes and digitalizes the extracted codes.

Fig. 1 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.

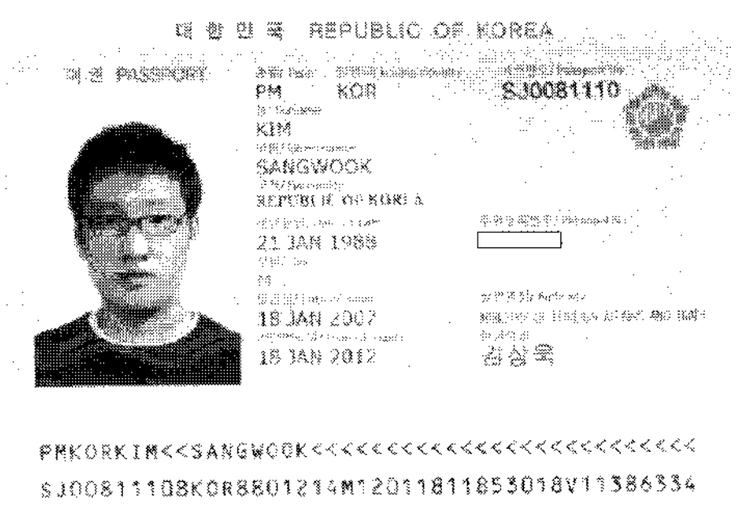

Fig. 1 An example of passport image

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

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of maximum ratio are selected as code sequence blocks. Fig. 2 shows the edge image generated by applying the Sobel masking to the image in Fig. 1. Fig. 3 shows the results generated by applying the horizontal *smearing to the edge image.*

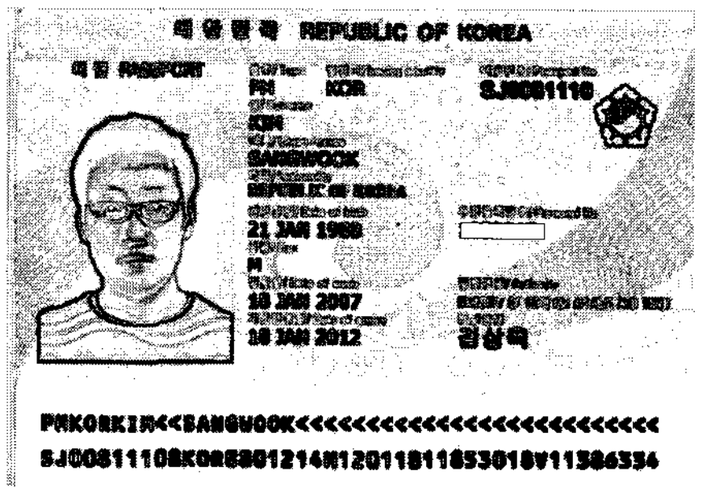


Fig. 2 Result of 3x3 Sobel masking in Fig 1

Fig. 3 Result of horizontal smearing in Fig. 2

This paper uses 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[3,4].

The paper uses the 2x2 mask shown 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.

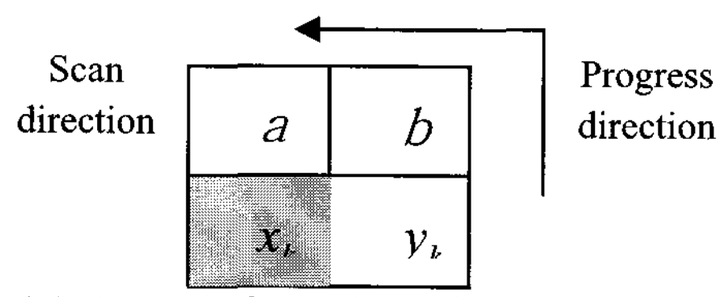


Fig. 4 2x2 mask for 4-direction contour tracking

The individual codes are extracted by applying the CDM (Conditional Dilation Morphology) masking to the areas corresponding to code sequence blocks in the original passport image. We apply CDM(Conditional Dilation Morphology) masking to the result of binarization to recover 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[5].

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

Fig. 5 describes the convergent procedure of CDM mask applied form in the direction of top, bottom, left and right. The CDM mask applied text region is smeared vertically and horizontally. We distinguish the individual codes using vertical coordinates from the vertical smeared text region and define the size of individual codes using horizontal coordinates.

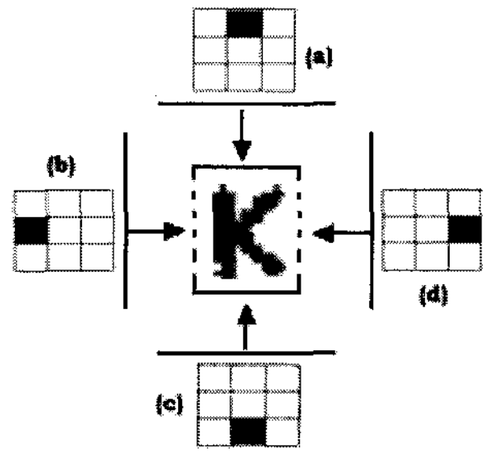


Fig. 5 CDM mask applied form

Finally, 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.

III. RECOGNITION of PASSPORT CODES USING ART2-BASED RBF NEURAL NETWORKS

The ART2 architecture was evolved to perform learning for binary input patterns and also accommodate continuous valued components in input patterns [6, 7]. In the ART2 algorithm, connection weights are modified according to the calculation of mean values of all input patterns. Then the cluster center is calculated by adapting it to the new pattern. However, the averaged mean value of the difference in input vector and connection weight is used for comparison with the vigilance factor, which

leads to the possibility of an input pattern being classified to a similar cluster having different properties. This could happen particularly in cases where the pattern dimensionality (N in equation 3) is large and one feature drastically differs from the cluster center but it's impact is minimized due to averaging all differences (see equation 3). When the traditional ART2 algorithm was applied to the recognition of container identifiers, it was observed that the recognition rate declined due to the classification of such different input patterns to the same cluster.

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[8].

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[9], this paper enhanced the RBF network to classify a new pattern to a new cluster, having no influence on existing clusters. The hybrid 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.

In the ART2-based hybrid 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.

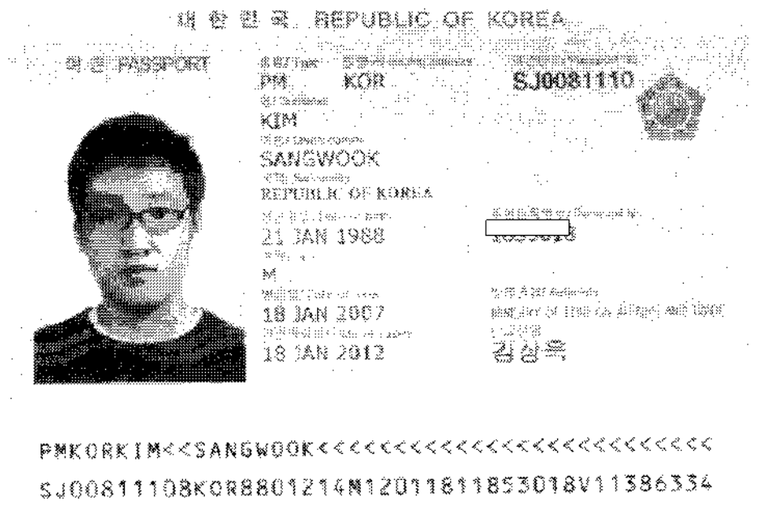
If the output vector of winner node is less than the vigilance parameter, the input pattern is classified as the same pattern; otherwise it is classified as the different pattern. In the former case, the connection weight is modified to reflect the similar property of input pattern to the weight. The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

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

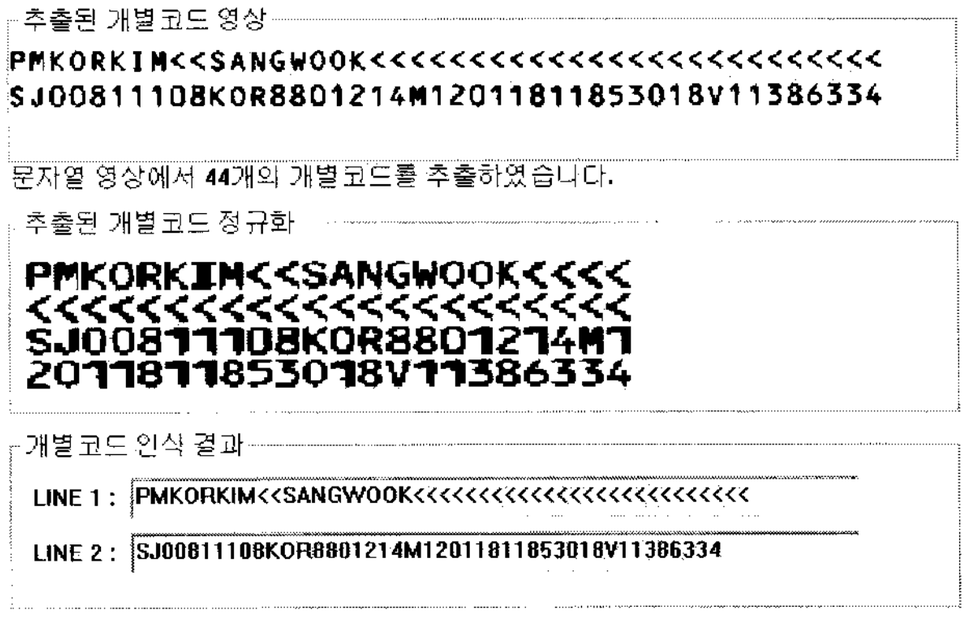
where u_k is the number of updated patterns in the cluster corresponding to the winner node.

IV. EXPERIMENTAL RESULTS

For performance evaluation, we implemented the proposed algorithm and experimented on an IBM-compatible PC with Intel Pentium-IV 2GHz CPU and 256MB RAM. And the 20 passport images of 600x437 pixel size were used in the experiments. Fig. 6(a) shows an example of passport image and Fig. 6(b) shows the result of individual code extraction from the passport image.



(a) Example of passport image



(b) Example of individual code extraction

Fig. 7 Example of individual code and picture extraction

Table 2 shows the number of code sequence blocks and individual codes extracted from the 20 passport images. The extracted individual codes contained 1140 alphabetic codes and 620 numeric codes. In the paper alphabetic codes and numeric ones were used separately in the learning and recognition experiments.

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

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

Table 3 shows the result of learning experiment in the enhanced RBF network using 880 individual user codes extracted from 10 passport images. In the learning experiment, when the vigilance parameter was set to 0.2, the ART2-based hybrid 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 ART2-based hybrid network

	Number of nodes created in the middle layer	Number of Epoch
ART2-based hybrid network	94	2721

This paper divided 20 passport images to two groups: 10 images used in learning and 10 images not used in learning. To evaluate the recognition performance, the ART2-based hybrid network was applied to each group individually. Table 4 shows the result of recognition experiment on each group. The ART2-based hybrid network recognized all individual codes extracted from 20 passport images.

Table 4. Result of recognition experiment in the ART2-based RBF neural network

	Image group used in learning	Image group not used in learning
Number of success/ Number of failure	880 / 0	880/ 0

V. CONCLUSIONS

Due to rapid increase of travelers globally, automatic and accurate processing of passports has become a necessity in order to avoid fraud and long waiting time for passengers. In this paper, we discuss an automated system for detection of forgeries in passports.

First, we proposed a novel method for the recognition of passports based on the ART2-basd hybrid network. In the individual code extraction phase, we extracted the code sequence blocks including individual codes by using Sobel masking, horizontal smearing and the 4-directional contour tracking based on the 2x2 mask. Then we extracted the individual codes form the code sequence blocks by using the CDM masking, and the vertical smearing. This paper proposed the ART2-based hybrid 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 ART2-based hybrid network was used to recognize individual codes. In the experiments for performance evaluation using 20 passport images, it was found that the ART2-based hybrid network outperforms traditional approach. Finally, as part of our future work, we plan to implement the recognition and complementary usage of the text information provided on the right-upper of passport image. Also, 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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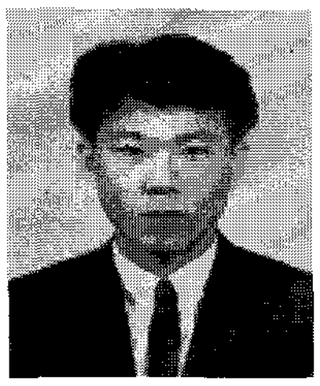

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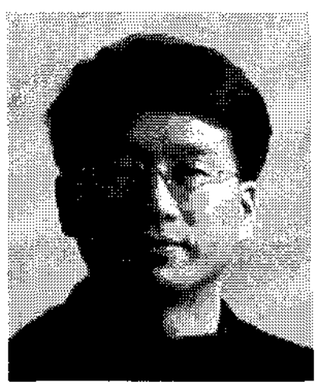

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