

Intelligent Immigration Control System by Using Passport Recognition and Face Verification

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Abstract

This paper proposes the intelligent immigration control system that authorizes the traveler through immigration and detects forged passports by using automatic recognition of passport codes, the passport photo and face verification. The proposed system extracts and deskews the areas of passport codes from the passport image. This paper proposes the novel ART algorithm creating the adaptive clusters to the variations of input patterns and it is applied to the extracted code areas for the code recognition. After compensating heuristically the recognition result, the detection of forged passports is achieved by using the picture and face verification between the passport photo extracted from the passport image and the picture retrieved from the database based on the recognized codes. Due to the proposed ART algorithm and the heuristic refinement, the proposed system relatively shows better performance.

Key words : Passport Recognition, Deskewing, Passport Image Analysis, ART Algorithm, Face Verification

1. Introduction

Due to globalization and the advancement of travel vehicles, the number of overseas travelers is gradually increasing. The current immigration control system carries out the passport inspection manually and requires a long time for immigration, which inconveniences passengers. And the automatic passport inspection requires the precise processing so as to execute the critical functions such as the discrimination of passport forgery, the search for a wanted criminal or a person disqualified for immigration, etc[1]. So, for the automatic immigration management, the various automatic systems were proposed to recognize the passports using the refined neural network and the fuzzy RBF network, etc[1, 2, 3].

This paper proposes a novel intelligent passport recognition system, which is able to discriminate passport forgery by using the automatic recognition of passport codes, the passport photo and face verification. The proposed system, firstly, extracts and deskews the areas of passport codes from the passport image by applying the edge detection algorithm and the horizontal minimum value filter to the image. And for the recognition of passport codes, we proposed the new ART algorithm creating the adaptive clusters to the variations of input patterns. So, the proposed system applies the new algorithm to the extracted code areas and compensates heuristically the recognition result to get the precise passport code information. And, using the code information recognized, the passport photo and related information of the passport owner is retrieved from the

immigration management database. The proposed system measured the passport photo similarity to the face verification by using the correlation that considers totally the overall intensity, edge values and the color information, etc., and it performed the verification separately in the overall picture area and in the facial area to get higher reliability in the discrimination of passport forgery. The overall structure of the proposed system is the same as Fig.1.

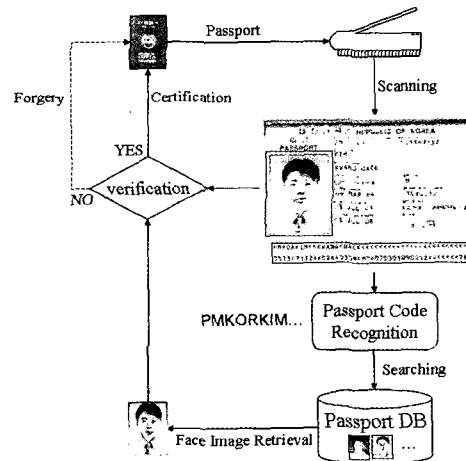


Fig. 1 Overall structure of the proposed intelligent passport recognition system

2. Extraction and Deskewing of Passport Codes

The passport image consists of the three areas, the passport photo area in the top-left part, the text information area including passport type, nationality, passport number, name, sex and date of birth etc., in the top-right part, and the passport

code area in the bottom part. The passport code area includes important information related to immigration inspection and the extraction and recognition of the passport code area is efficient for the automatic immigration management.

2.1 Extraction of Code Areas

The passport code area has the following characteristics: it consists of alphabetic and numeric characters and is arranged in a row horizontally, and the code characters consist of strokes with 1 or 2 pixels, making a clear distinction between the pixels of code areas and background pixels. The above-stated characteristics can be embodied by applying the edge detection algorithm such as the Sobel operation to the passport image. Because the interval between code characters is in the regular range, the code characters are able to be connected by using the horizontal $n*1$ minimum-value filter[3], called a smearing algorithm, which replaces n pixels being adjacent horizontally with the minimum pixel value among them. In the filter, the value for n has to be set to the maximum size among the intervals between code characters.

After applying the edge detection algorithm and the horizontal minimum-value filter to the passport image, the output image is binarized by using the iterative thresholding method. The connected objects are extracted from the binarized image by the connected component labeling method[4]. By eliminating the useless objects based on the characteristics that the code area is arranged in a row at the bottom of the passport image and is separated from the boundaries of the image, the passport code areas are extracted from the passport image.

The iterative thresholding method[5] used in this paper classifies the background and the feature pixels from the input image by using the stabilized threshold, which is obtained by performing the iterative operation that divides pixels into two clusters using the given threshold and updates the threshold using mean values of new clusters until the threshold is stable. The binarization process of the passport image by the iterative thresholding method is as follows:

Step 1. Set the initial threshold T^0

Step 2. Classify the background and the feature pixels using the threshold T^t determined at the previous step. And calculate the mean pixel values μ_B^t & μ_o^t for the background and the feature clusters, respectively.

$$\mu_B^t = \frac{\sum f(i,j)}{N_B} \quad (1)$$

$$\mu_o^t = \frac{\sum f(i,j)}{N_o} \quad (2)$$

where N_B and N_o are the number of pixels of the background and the feature clusters, respectively.

Step 3. Update the threshold value using μ_B^t & μ_o^t

$$T^{t+1} = \frac{\mu_B^t + \mu_o^t}{2} \quad (3)$$

Step 4. Exit if $T^{t+1} = T^t$. Otherwise, go to step 2.

The overall process of the code area extraction is the same as Fig. 2.

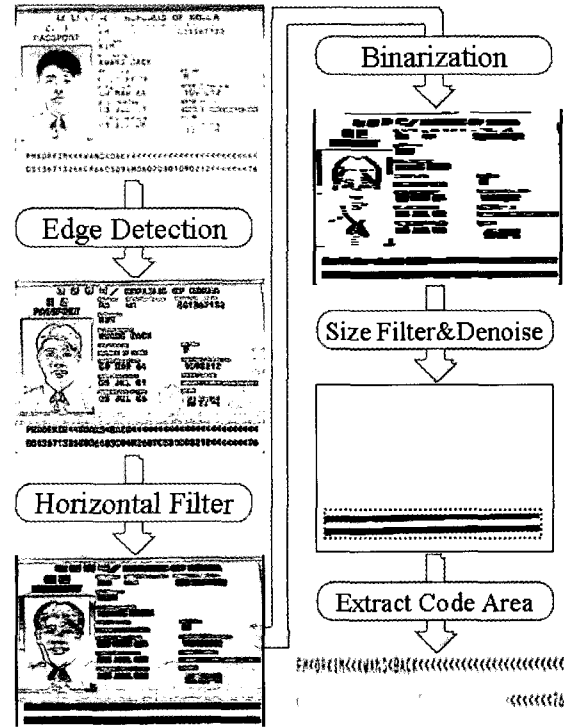


Fig. 2 Overall extraction process of passport code areas

2.2 Deskewing and Refinement of Passport Image

The passport image may be scanned at skew direction and the deskewing of the passport image is required essentially for post-processing such as code extraction and recognition, and the face verification.

This paper selected the code area with the longest width among the extracted code areas and calculated the angle between the line connected between the centers of the left and the right sides of the code area and the horizontal line in the image. And, the passport image is deskewed by rotating the pixels as much as the angle. This paper refined the coarse strokes of the code characters by using a 3*3 median filter to prevent the decline of the recognition rate on the low definition images.

3. Recognition of Passport Codes

The passport codes have in total 37 patterns that consists of 10 numeric characters(0~9), 26 upper-case alphabetic characters(A~Z) and 1 special character('<'). This paper assumed that the pattern of the number '0' is the same as the character 'O' and fixed the 36 patterns to the patterns being

recognized. Also, the ICAO 9303 OCR-B type font is used for the passport code.

To improve the recognition rate of passport codes with regular appearance, this paper proposed the new ART algorithm that creates the adaptive clusters to the variations of input patterns. The proposed ART learning algorithm is as follows:

Step 1. Define x_k as the k -th input vector, w_i as the connection weight vector of i -th cluster in the neural network.

Step 2. Perform the Exclusive-NOR operation on the newly-given x_k and w_i , and select a winner node with maximum value.

$$\mu_{i^*} = \max \left(\frac{\|x_k \odot w_i\|}{N} \right) \quad (4)$$

where N is the number of input nodes.

Step 3. Perform the similarity test for an input vector. If μ_{i^*} is greater than the vigilance parameter ρ , the input pattern is determined to be similar to the winner cluster and the input vector which makes it to be included in the winner cluster. To reflect it, update the center vector of the winner cluster using Yager's intersection operator.

$$\mu_{i^*}^{t+1} = 1 - \wedge \left(1, \sqrt{(1-x_k)^2 + (1-w_{i^*})^2} \right) \quad (5)$$

If μ_{i^*} is lower than ρ , the input pattern is determined to be dissimilar with the winner cluster and the new cluster including the input vector is created.

Step 4. Repeat Step 1 to Step 3 until the learning of all input patterns is complete.

4. Photo Verification

While the automatic recognition of passport codes improves the efficiency of immigration management by retrieving and comparing the basic information of a passport owner using the recognized codes, it may not support the precise discrimination of a passport forgery. For example, in the case that the photo in the passport is replaced with another photo, only the automatic code recognition cannot discriminate the passport forgery. So, this paper proposes the whole photo verification method for the discrimination of passport forgery, which extracts the passport photo area from the passport image and verifies it by measuring the similarity between the extracted passport photo and the passport photo image retrieved from the passport database.

4.1 Extraction of The Passport Photo Areas

The photo in the passport is placed at the left-upper side of the passport code areas. It is extracted formerly and the position of the area of the photo in the passport image may be

approximately estimated by using the relative distance from the passport code areas and the information on the boundary lines of the photo area. But, when the boundary lines of the photo area is not clear due to the similarity of color information between the backgrounds of the picture area and the whole passport image, it is difficult to extract the photo area from the passport image.

This paper extracted the photo area from the passport image by using the information on the picture image retrieved from the database. This method, firstly, uses the relative position information, estimates the search area including the photo area and secondly, compares the candidate areas in the search area with the retrieved photo image, which determines the candidate area with the highest similarity as the photo area. In the search process of the photo area, the size of the candidate area has to be set to the size of the photo image retrieved from the database. The overall process of the photo area extraction is shown in Fig. 3.

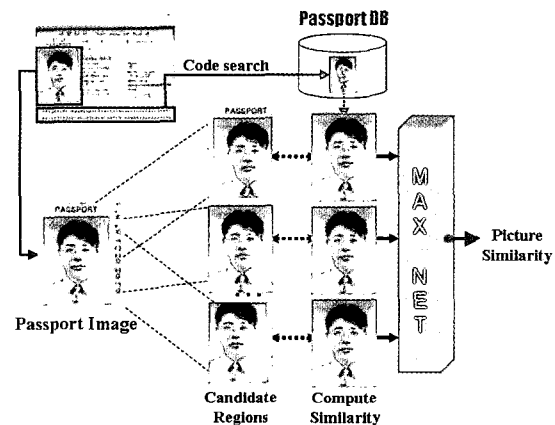


Fig. 3 Overall process of the photo area extraction

4.2 Similarity Measurement

This paper uses correlation[6] as the similarity measurement between the photo area extracted from the passport image and the photo image retrieved from the passport database. Generally, the Hamming distance or the Euclidean distance is used as the similarity measurement between two vectors. The measurements are very sensitive to the overall change of intensity and color values, etc., whereas the correlation represents the positive or negative relation between two vectors using the mean and the standard deviation of vectors. So, considering the poor environment of operation, the correlation is the stable and suitable measurement of similarity in the photo verification for the passport image.

The correlation of two-dimensional vectors is calculated by the correlation coefficient shown in Eq.(6). If the correlation coefficient reaches close to 1, it means that the two vectors have a positive correlation, and if the correlation coefficient reaches close to -1, it means that the two vectors have the

negative correlation. If the two vectors are irrelative mutually, the correlation coefficient will reach close to 0.

$$r(T, R) = \frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (T_{i,j} - \mu_T)(R_{i,j} - \mu_R)}{M \times N \times \sigma_T \times \sigma_R} \quad (6)$$

where, T and R are the two-dimensional vectors indicating photo images being compared, M and N are the vector sizes of the two images T and R , μ_T and μ_R are the means of T and R , and σ_T and σ_R are the standard deviations of T and R .

Fig. 4 shows the overall process of the feature extraction of photo images and the similarity measurement.

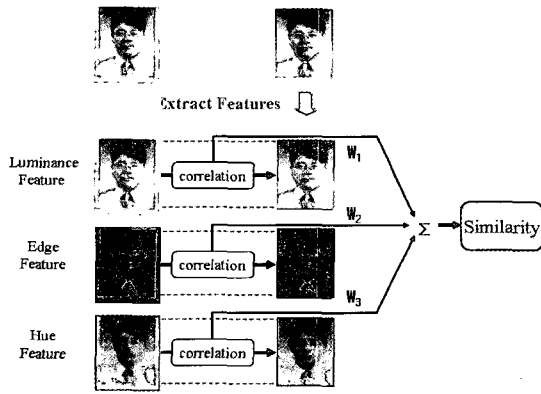


Fig. 4 Feature extraction and similarity measurement of photo image

4.3 Photo Verification of Passport Image

The features used for image matching are the color distribution, morphological information and frequency information, etc. For photo verification, this paper uses various features such as luminance, edge vale, HSV color distribution, RGB color distribution, normalized RGB color distribution, YIQ color distribution and YCbCr color distribution[7-10].

The discrimination algorithm of passport forgery using photo verification is as follows:

Step 1. Measure every feature value from the extracted photo area and the retrieved photo image.

Step 2. Calculate the correlations between feature values of the same type

Step 3. Calculate the weighted sum of the correlations.

Step 4. Compare the measurement with the given threshold. If the measurement is lower than the threshold, it is discriminated that the passport is possible to be forged.

This paper, for the improvement of processing performance, applied the combination of a few features having the superior discrimination to the correlation measurement.

5. Face Verification

This paper proposes face verification of the passport image for precise and reliable discrimination of passport forgery[11]. The combination of face verification and photo verification is to enable discrimination in forged passports by image synthesis of facial areas in the photo.

5.1 Construction of Face Template Database

The current passport database does not provide additive information on the face of the passport owner, and the construction of the face template database must precede the face verification. The construction process of the face template database is as follows: Firstly, the face templates are constructed by extracting facial areas from multiple passport photos and averages them. Secondly, it compares candidate areas of the passport photo image with the face template, and the area with the highest similarity is determined as the face template image of the passport image. The template image is saved to the passport database as one field of passport information. Therefore the passport database is able to provide the whole photo image and the face template image for face verification. The construction process of face template database is the same as Fig. 5.

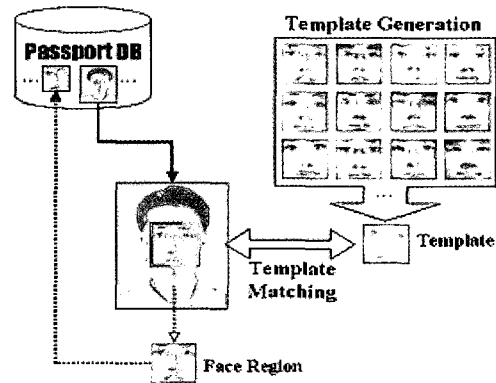


Fig. 5 Construction of the face template image database

5.2 Face Verification

The face verification consists of the extraction of an area with the skin color and the matching of the extracted area and the face template. First, the extraction of a skin-color area from the passport image is achieved by using the HSV color model. The features of skin-color areas such as the distributions of color, saturation and intensity are to be calculated heuristically in advance. For the removal of image noises, the passport image is reduced to 1/10 size of the original image and again, the output image is enlarged 10 times the original size to create an image with the original size. And, the binarization of the output image assists to extract the area with the skin color from the original image. The extraction of a skin-color area reduces the search area and improves the

processing speed. If the extraction were to fail, the whole passport image is set to the search area.

The process of face verification is similar to the photo verification. Comparing the candidate areas with the regular size of the skin-color area and the face template retrieved from the database, this paper determines the candidate area with the highest correlation as the facial area and discriminates whether or not the passport is forged. If the correlation is lower the given threshold, it is determined that the passport may be forged.

This paper measures and evaluates various features from passport images used in an experiment. And, for the improvement of processing speed and reliability, this paper applied Luminance, Edge value and RGB color distribution to the correlation measurement for photo verification and, Hue, I-value of TIQ color model, Cb-value of YCbCr color model for the face verification. The overall process of code recognition and face verification for the passport image is shown in Fig. 6.

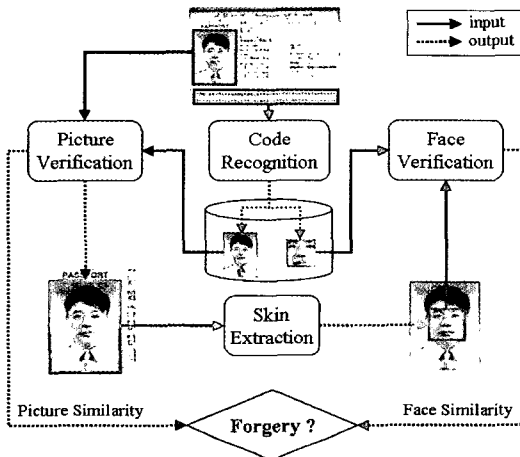


Fig. 6 Overall process of passport recognition and verification

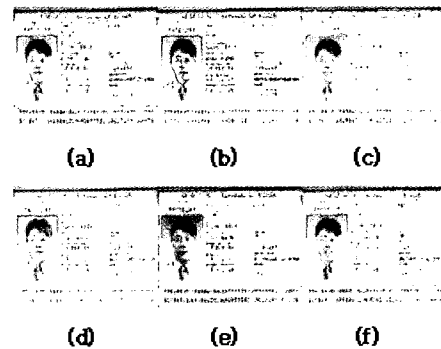
6. Experiment and Performance Evaluation

This paper, for performance evaluation, implemented the proposed system in Visual C++ 6.0 and experimented on an IBM Compatible PC with Intel Pentium-IV 2.8GHz CPU and 512MB RAM. In the experiment for passport code recognition, 888 code characters with various sizes were extracted from 16 passport images originally scanned and normalized vectors with the size of 20x20 were applied to the learning algorithm so that 344 clusters were created in the proposed ART algorithm. The passport images used in this experiment were scanned at 300 DPI by a HP ScanJet 6350C scanner. For the experiment of the photo and face verification, we created the 16 forged passport images in which the whole photo was replaced with another photo and the other 16 forged images with synthesized facial areas. Also, as shown in Fig. 7, to

evaluate the flexibility of the various operation environments, we used 336 varied passport images that were created by applying the image operations such as noise insertion, contrast change, intensity change and saturation change to 48 original and forged passport images.

6.1 Experiment of Passport Code Recognition

Table 1 shows the recognition rate of passport codes on the 336 passport images. In the recognition experiment, the recognition of the code area was regarded as a failure if all characters in the code area were not recognized. As shown in Table 1, the recognition experiment on the original passport images without any refinements showed a low recognition rate of about 23.1%. The result was incurred by the skew scanning of passport images and many errors occurred at the separation of characters from the code areas. When the image deskewing and refinement operations were applied to the passport images, a better and stable recognition rate of about 98.6 % was shown.



(a) Insertion of Noise (b) Increase in Contrast
(c) Decrease in Contrast
(d) Increase in Intensity (e) Decrease in Intensity
(f) Decrease in Saturation

Fig. 7 Variations of original passport image

Table 1: Performance result of passport code recognition

Image Variation	Original Images			Refined Images		
	# of Success	# of Error	Recogn. Rate(%)	# of Success	# of Error	Recogn. Rate(%)
Original Image	9	39	18.8	46	2	96.0
Noise Insertion	6	42	12.5	47	1	97.9
Contrast Increase	12	36	25.0	48	0	100
Contrast Decrease	12	36	25.0	47	1	97.9
Intensity Increase	6	42	12.5	48	0	100
Intensity Decrease	9	39	18.8	47	1	97.9
Saturation Decrease	9	39	18.5	48	0	100
Total	63	273	23.1	331	5	98.6

6.2 Similarity Measurement of Passport photo

For the correlation measurement in the photo and face verification, the paper measured various features from the passport images such as: luminance, edge value, HSV color distribution, RGB color distribution, Normalized RGB color distribution, I-value and Q-value of YIQ color model and Cb-value and Cr-value of YCbCr color distribution. And in this paper, the features were declared as Luminance, Edge, Hue, RGB, RGB-N, YIQ_I, YIQ_Q, YCbCr-Cb and YCbCr-Cr, respectively. The experiment for photo and face verification measured and compared the correlation between the 16 passport photos saved in the database and the 112 photos extracted from forged and varied passport images.

Table 2: Feature evaluation for photo verification

Feature Type	Corr. with original pictures	Corr. with forged pictures	Diff.	Rank
Luminance*	0.980	0.390	0.590	3
Edge*	0.798	0.153	0.646	1
Hue	0.933	0.374	0.558	5
RGB*	0.980	0.390	0.590	2
RGB-N	0.893	0.336	0.557	6
YIQ-I	0.959	0.455	0.504	7
YIQ-Q	0.722	0.252	0.470	9
YCbCr-Cb	0.966	0.385	0.581	4
YCbCr-Cr	0.934	0.458	0.476	8
Average of selected features(*)	0.919	0.311	0.608	

Table 3: Feature evaluation for face verification

Feature Type	Corr. with original pictures	Corr. with forged pictures	Diff.	Rank
Luminance	0.974	0.673	0.301	9
Edge	0.939	0.615	0.324	7
Hue*	0.801	0.309	0.493	2
RGB	0.972	0.659	0.313	8
RGB-N	0.923	0.529	0.394	6
YIQ-I*	0.950	0.518	0.432	3
YIQ-Q	0.855	0.457	0.398	5
YCbCr-Cb*	0.929	0.406	0.524	1
YCbCr-Cr	0.946	0.546	0.399	4
Average of selected features(*)	0.893	0.411	0.483	

Analyzing the results shown in Table 2 and 3, for the improvement of processing speed and reliability, this paper applied selective features to the correlation measurement which

is as follows: Luminance, Edge and RGB for photo verification, and Hue, YIQ-I, YCbCr-Cb for face verification.

In the verification experiment, the correlation threshold values each being different were used for the original passport images and the forged images by applying the different weights to feature values. In the case that the correlation threshold values were given 0.8 equally, it showed a relatively good performance with FAR(False Accept rate) of 3.1% and FRR(False Reject rate) of 2.7%.

Table 4: Performance of the photo and face verification in terms of threshold values

Threshold for photo verification	0.92	0.86	0.80	0.74	0.68	0.62
Threshold for face verification	0.89	0.84	0.80	0.75	0.70	0.65
Normal-Pass(%)	90.2	93.8	97.3	98.2	98.2	98.2
Normal-Alarm(%)	9.8	6.3	2.7	1.8	1.8	1.8
Forgery-Pass(%)	1.3	2.2	3.1	4.9	3.1	4.9
Forgery-Alarm(%)	98.7	97.8	96.9	95.1	96.9	95.1

7. Conclusions

This paper proposes an intelligent immigration control system that authorizes the traveler immigration and detects forged passports by using automatic recognition of passport codes and the photo and face verification. The proposed system extracts and deskews the code areas from passport images by using properties of passport code areas. And this paper proposed the novel ART algorithm and applied it to the extracted code areas for code recognition. After compensating heuristically the recognition result, the discrimination of forged passports is achieved by using the photo and face verifications between the photo extracted from the passport image and the picture retrieved from the database based on the recognized codes. In photo and face verification, the correlation was used as the verification measurement and it was measured using Luminance, Edge value, RGB color distribution for the photo verification, and using Hue, YIQ-I value, YCbCr-Cb value for the face verification. When the correlation threshold of 0.8 was given, the verification experiment on the forged and varied passport images showed a relatively good performance with FAR(False Accept rate) of 3.1% and FRR(False Reject rate) of 2.7%.

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 for improvements of flexibility to the site environment, we plan to

implement face verification on the actual face image entered directly through the CCD camera at the immigration gate.

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