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Full-Accuracy Face Recognition with a Minimum Number of Features of the Face Region

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Abstract

A minimum number of features for 100% face recognition accuracy is developed in this paper. Such number is based on dividing the detected face region into vertical and horizontal segments. A simple technique that regards the pixel mean of a segment as a feature is adopted. Algorithms and flowcharts to detect the minimum of the Euclidean Distance (ED) between a test face image and a matching database (DB) one are discussed. A threshold is selected to differentiate between a genuine acceptance and a false acceptance of an imposter. The minimum number of features is found to be 21. Comparison with previously-published techniques shows the superiority of the proposed technique regarding accuracy. Results were obtained using the ORL face database.

Keyword: Face recognition, Vertical and Horizontal segments, Minimum number of features, Full accuracy

1. INTRODUCTION

Biometrics is the unique measurable characteristic that automatically recognizes an individual based on his physical and behavioural characteristics [1].

Physiologists usually deal with the physique of the body such as the face, palm, iris, fingerprints and DNA [2]. On the other hand behaviourists are keen on the physical behaviour of a person such as keystrokes, voice and signature.

Over the last few decades lots of work have been done on face detection and recognition [3] as it is the most effective way for person identification [4] since it doesn’t need human cooperation [5] and so, it became an important topic in biometrics. In fact lots of methods were introduced for face detection [6,7,8,9,10] and recognition [8,11,12,13] which may be considered as recognition milestones.

2. FACE IMAGE DATASET

The ORL face database [14] which is composed of 400 images for 40 persons each of size 112 x 92 is utilized in this work. The database images were taken at different lighting, times and facial expressions. The faces are in an upright position with frontal view and slight left or right rotations. Samples of such ten images per person are shown in Fig. 1.

A database was created with 200 images of 20 individuals. Out of these 10 images of each individual, 5 images were used as a training set and the remaining images were used for testing (selected randomly). Thus, the ratio between the training set and the test set is 1:1.

3. PRE-PROCESSING

All test images will be compared with the all database face images using a correlation method for establishing the degree of probability that a linear relationship exists between two measured quantities.

The Pearson’s correlation coefficient for monochrome digital images is defined as in equation (1) [15]

$$r = \frac{\sum_i (x_i - x_q)(y_i - y_q)}{\sqrt{\sum_i (x_i - x_q)^2}\sqrt{\sum_i (y_i - y_q)^2}} \qquad (1)$$

Fig. 1. Sample Images from Face Database

Where, x_i and y_i are intensity values of i^{th} pixels in the 1st and 2nd images respectively. Also, x_q and y_q are the mean intensity values of the 1st and 2nd image respectively. The correlation coefficient has the value r=1 if the two images are absolutely identical, r=0 if they are completely uncorrelated and r= -1 if they are completely anti-correlated [16].

The correlation percentage for the original face images is 84%. To overcome this problem, pre-processing is needed to extract the most important features in the image.

The most important features are extracted from the face region only i.e. without its background. So the input image is first binarized and the face region is selected and resized to 100×60 as shown in Fig. 2 and Fig. 3.

After the pre-processing step, all test images are compared with all database images using the correlation method. The correlation percentage for the detected face images becomes 100%.

Fig. 2. Image binarization

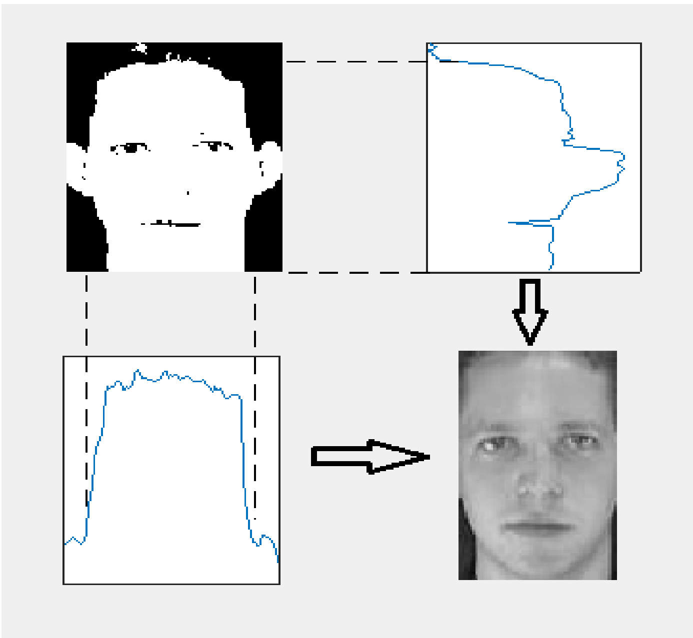

Fig. 3. The face region

4. PROPOSED APPROACH

4.1 Row-Means Method

The face image produced from the pre-processing step with size 100×60 is used for the Row-Means Method. In this method the pixel mean of each row in the face image is computed. The resulting row means are considered as the feature vector of a face image with the size of 100 elements. The Euclidean distance was then employed to ascertain the matching distance between feature vectors.

Fig. 4 and Fig. 5 show feature vectors of two images for the same person and the feature vectors of two images for different persons using Row Means Method respectively.

Fig. 6 shows an example for the ED of a test image of index 6 of the 100 DB images. A true matching between the test image and the images of the same face belonging to the sae subject takes place when the ED is less than the threshold level.

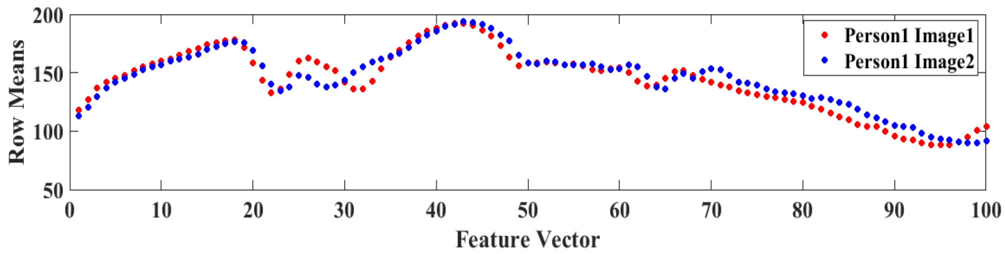

Fig. 4. Different Row Means feature vectors for the same person

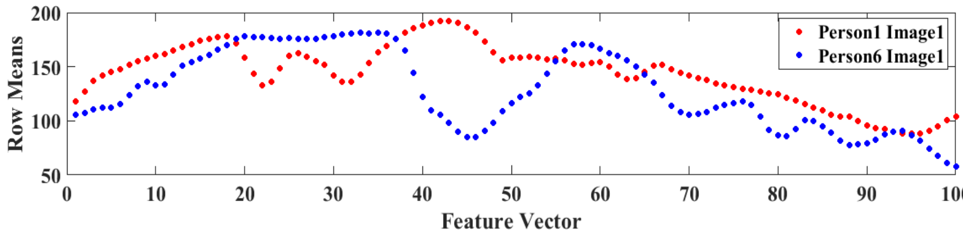

Fig. 5. Different Row Means feature vectors for different persons

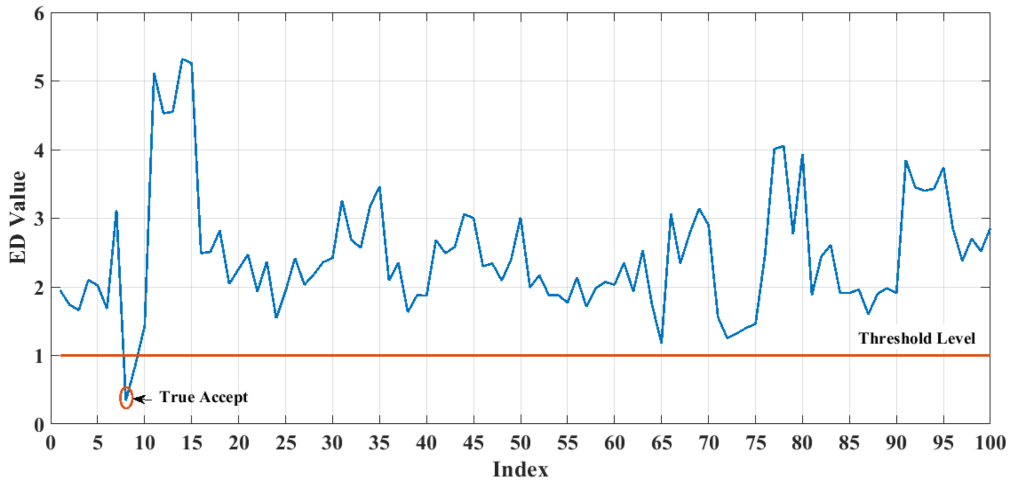

Fig. 6. Recognition of a test face of index 6 (person 2 image 1) with 100DB images using Row Means Method

4.2 Combined Row-Column Means Method

The face image produced from the pre-processing step with a size 100×60 is also used for the Combined Row-Column Means Method. In this method, we compute the mean of each row and of each column in the face Image. The resulting rows and columns means form a feature vector of the image with size of 160 (100+60) elements. The Euclidean distance is then employed to ascertain the matching distance between feature vectors.

Fig. 7 and Fig. 8 show feature vectors of two images for the same person and the feature vectors of two images for different persons using Row-Column Means Method respectively.

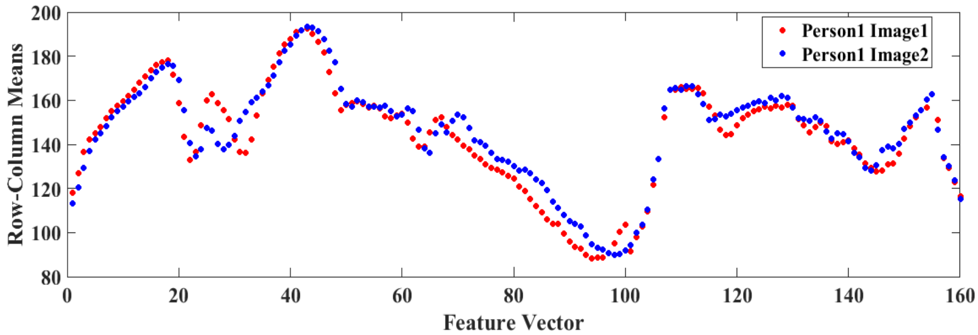

Fig.7. Different Row-Column Means feature vectors for the same person

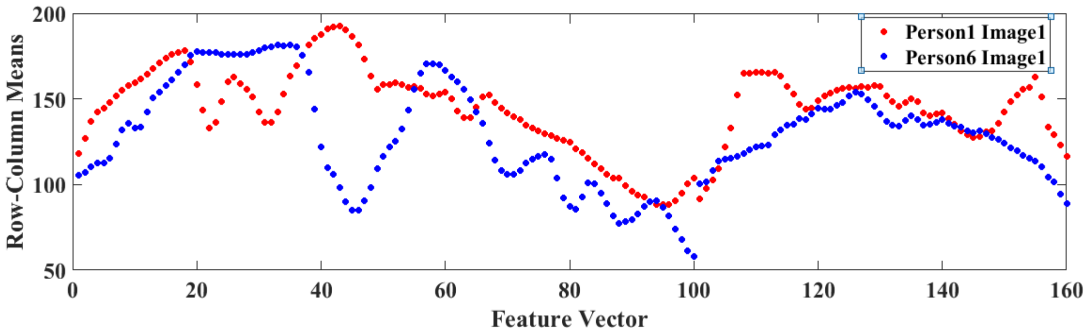

Fig.8. Different Row-Column Means feature vectors for different persons

4.3 Horizontal-Vertical Partitions Method

To reduce the number of features that may produce 100% recognition accuracy, the face may be divided into vertical partitions each incorporating a number of columns or into horizontal partitions with a number of rows each. Starting with two-column or two-row partitions and increasing this number gradually and testing for 100% accuracy.

Until a minimum number of partitions is reached (i.e. with the maximum no. of columns or rows each.) this number may represent the required minimum no. of features for full accuracy recognition.

As shown in Table I, the number of rows and columns of each partition is increased gradually to show the minimum number of partitions that may keep the best accuracy (100%).

However it was found that Horizontal partitions with up to five rows each and Vertical Partitions with up to ten columns each together produce the required full accuracy i.e. 100%. This means that the feature vector length decreases to only 26 elements instead of the starting 160 elements as indicated in Table 1.

TABLE 1. REDUCTION OF FEATURE-VECTOR LENGTH IN THE ORIGINAL ROW-COLUMN MEANS METHOD

No. of row	No. of column	Feature vector length	Accuracy
1	0	100	99%
1	1	160	100%
2	2	80	100%
4	4	40	100%
5	5	32	100%
5	6	30	100%
5	10	26	100%
10	10	16	99%

4.4 Modification of Horizontal-Vertical Partitions Method

Because the human forehead does not contain essential changes, it may be considered as one partition as shown in Fig. 9.

This modification gave the same accuracy of 100% by using up to only 15 Horizontal Partitions and 6 Vertical Partitions together. The feature vector length would reduce to 21 elements only instead of 160.

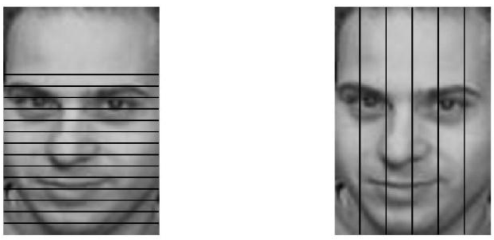

Fig. 9. Detected face with Horizontal and Vertical Partitions

5. ALGORITHM

The Horizontal-Vertical Partitions Method algorithm may be described through the following steps

Step 1: Read the database gray level image (Size=112×92).

Step 2: Determine the face region with size (100×60).

Step 3: Divide the face into one forehead partition and 14 equal horizontal ones in addition to 6 equal vertical partitions.

Step 4: Apply partition means method to form vectors with size of 21 elements each (feature vector).

Step 5: Repeat steps 2) through 4) for every database image.

Step 6: Read the query image.

Step 7: Apply step 2) through 4) for the query image so as to obtain its feature vector FV.

Step 8: For every database image 'i' and a query image 'q', compute the Euclidean distance (ED) using the following formula:

$$ED = \sqrt{\sum_{1}^{N}(\mathrm{FV_i} - \mathrm{FVq})^2} \qquad (2)$$

Step 9: Determine the image with minimum ED and this corresponds to the best match.

However the proposed method may be described through two steps. In the first step a face template for each image in the database is created and stored as in Fig. 10. In the second step, the face template for a query image is created and then a comparison based on the Euclidean distance is made. The system can accept or reject a person according to a value of ED less than the threshold as stated in Fig. 11.

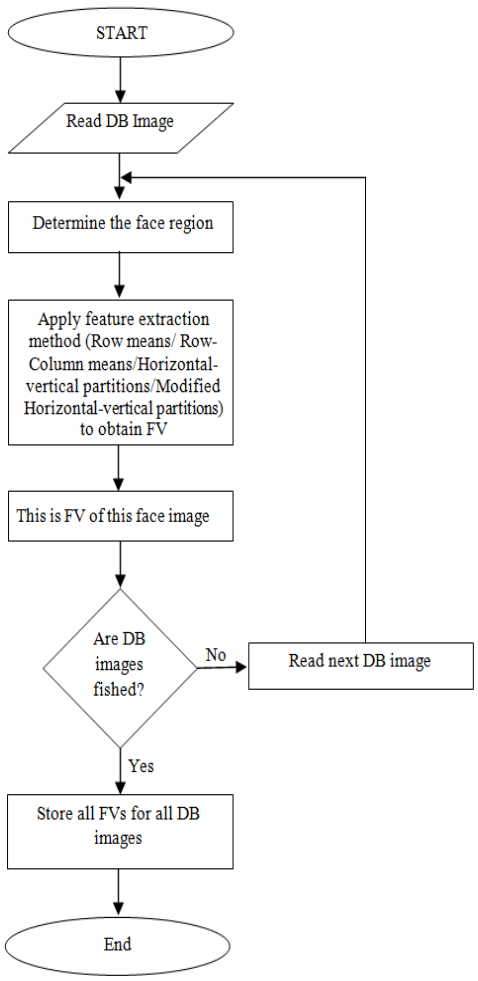

Fig. 10. Flow chart of DB face template creation

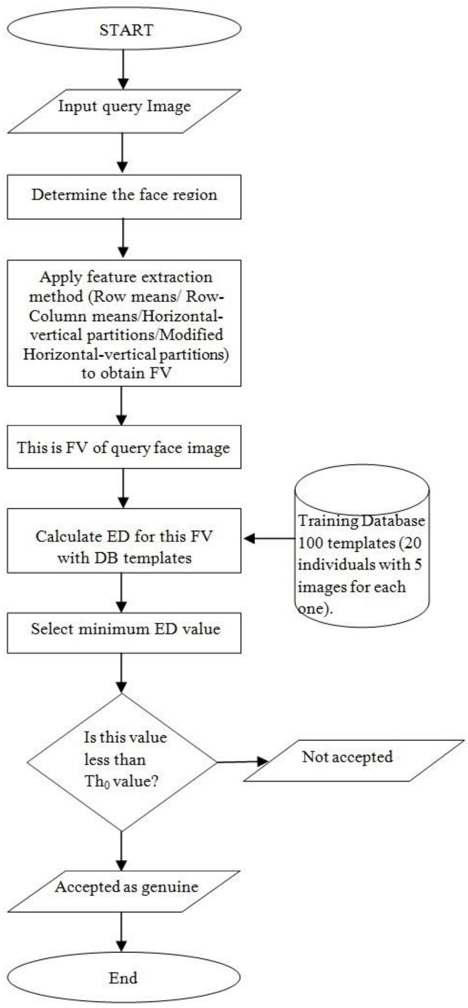

Fig. 11. Flow chart of person identification.

6. PERFORMANCE RESULTS

The Euclidean Distance (ED) is used for classification of face templates. Two templates are considered to be matching if the ED is lower than a specific threshold. A decision can be taken in the matching step, based on threshold values. That is to say that a similarity between two face images may be evaluated based on their ED if it below a certain threshold.

ED of the feature set was used as a similarity measure. The direct ED between the database image i and the test image q can be given as in equation (2), where FV_i and FV_q are the feature vectors of a database image i and the test image q (query) respectively and each is of size "n".

Fig.12 and fig. 13 show the identification accuracy at different threshold values obtained with the Horizontal-Vertical Partitions Method and Modified Horizontal-Vertical Partitions Method respectively.

Optimum threshold is seen to be of 4.5value using the 26 features as shown in fig. 12. With the modified 21 features, fig.13 shows an optimum threshold of 3.7.

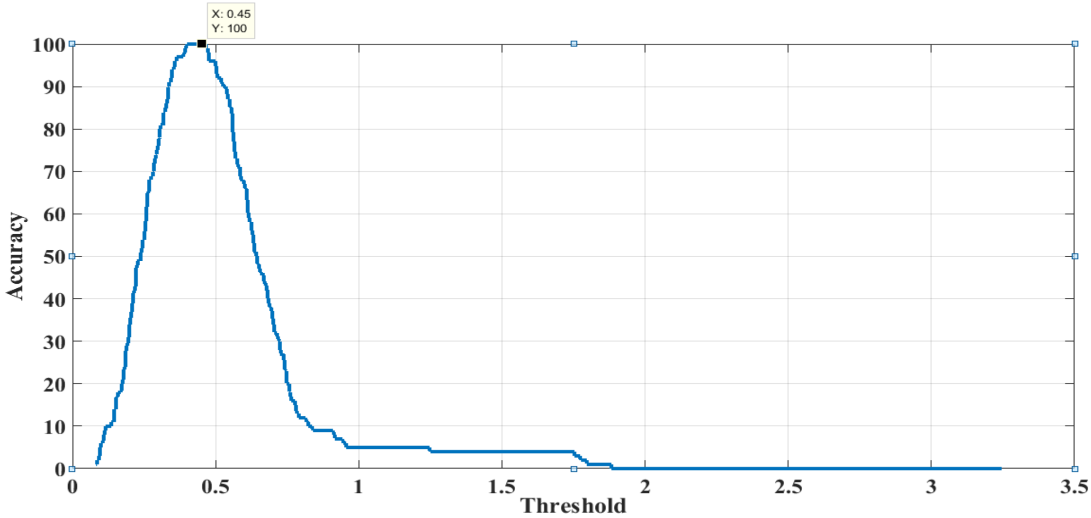

Fig.12. Identification accuracy obtained for face recognition using Horizontal-Vertical Partitions Method (26 features) at different threshold values.

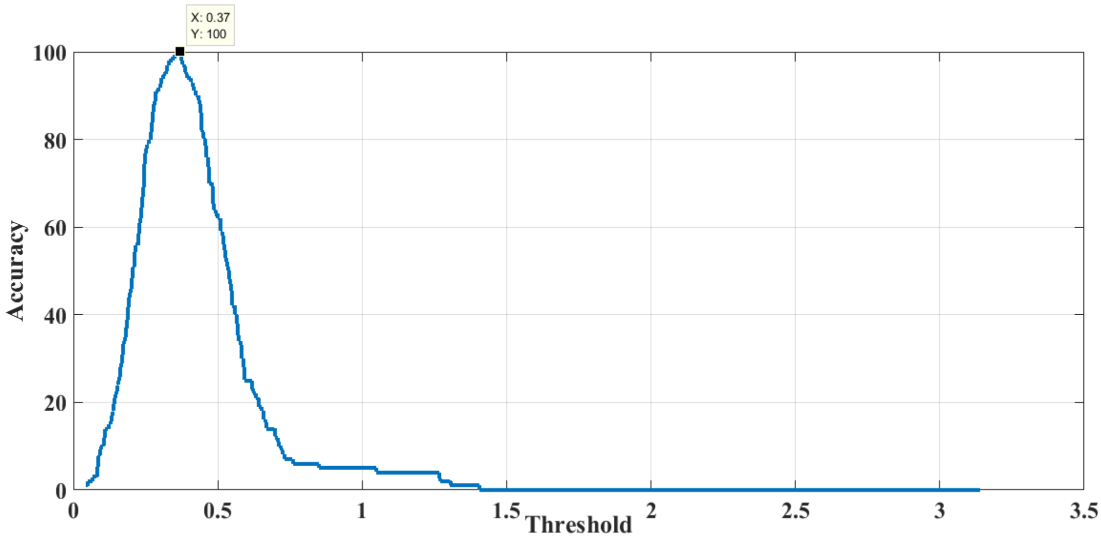

Fig.13. Identification accuracy obtained for face recognition using Modified Horizontal-Vertical Partitions Method (21 features) at different threshold values.

7. CONCLUSION

The proposed method is based on dividing each face region into a number of partitions that has been shown to be optimum. This number is of fifteen horizontal and six vertical partitions. Extracting features from such partitions in terms of their means produced 100% accuracy with only 21 face features.

It should be noted that, the face-features number used in the proposed method is the optimal number compared to the approaches introduced in [17]. The minimum number of features considered in [17] to achieve accurate face recognition was 261 features. In this paper, this number is reduced to about 8% only i.e. 21 features.

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