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Face Recognition Using Contour-Based Multiscale Distance Matrix

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***Abstract*—Face Recognition is an emerging approach in the recent years. In this paper, the formulation of a face recognition approach using contour-based shape descriptor named Multiscale Distance Matrix (MDM) is developed using the concept of inner-distance in the distance matrix instead of the Euclidean distance. In the proposed scheme, first the similarity in the shape of the face is found by taking a sample number of boundary points on the contour of the face image and the Multiscale Distance Matrix (MDM) is constructed and second the closest resemblance of the face image using the geometrical characteristics is expected to be found. MDM is a contour-based and global based approach that extracts global features of a shape. The values in the proposed distance matrix are the inner-distances calculated between two given sample boundary points on the contour. Inner distance is defined as the length of the shortest path between two points within the shape boundary. The MDM method avoids the time-consuming point-wise matching used in most of the previous shape recognition algorithms. For 100 test images as query, MDM gave a performance rate of 80 percent in the retrieval of face images.**

***Keywords*—Face recognition, Multiscale Distance Matrix (MDM); Distance Matrix (DM); Inner-distance; Nearest Neighbour Classifier.**

I. INTRODUCTION

Image processing refers to the analysis and manipulation of a digitized image, especially in order to improve its quality. The input is taken as an image and the output is a processed image of the desired criteria. The processing of an image includes the image display, image editing and manipulation, image enhancement, feature detection and extraction, printing and image compression. In image processing, face recognition is considered as an emerging field of research.

It is requisite in the current era to do every activity electronically so as to get better, fast and accurate results. Some of the applications of face recognition is used in drivers licenses, passports, biometrics, forensics, desktop logon, tagging of people, image search etc. Biometrics uses the physical characteristics and behavioral characteristics of an individual for personal identification. Some of the physical characteristics are finger-scan, face recognition, iris-scan, retina-scan and hand-scan. Behavioral characteristics include voice-scan, signature-scan and keystroke-scan. This has paved the way to concentrate further more on the field of face recognition. There are two types of comparisons in face recognition such as verification and identification. In verification, the system compares the given image of the individual with a proof provided and concludes to a yes or no decision. In identification, the image of a person is checked against each individual in a database. Our paper does the identification type of face recognition. In our work, shape is considered as the major criteria to recognize the face.

Shape is the first thing that people recognize faster when perceived. Shape gives an external geometric property of an object. The development of the face recognition approach is motivated by identifying or verifying whether he/she is that person from a digital image. The scope of the work is to achieve a better face recognition approach by extracting the shape of the face [1]. There are two contour-based approaches such as local-based approach and global-based approach. Local-based approach extracts local features of an image and global-based approach extracts the global features of an image. Extracting the shape of the face is achieved by taking a sample number of point on the contour or boundary of the face image and the distance between each and every points is calculated.

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Then inner-distance between each and every point is found and it forms the distance matrix. Inner-distance is defined as the shortest path between two points within the shape contour. Using this distance and after some sub-space analysis, a Multiscale Distance Matrix (MDM) is build. The MDM captures the shape geometry. This is used to recognize the similar face images from the database and further to closely relate the face image with the input dataset, geometric characteristics of the face are chosen. The experiment was conducted for 100 test images against 300 images in the database.

The rest of this paper is organized in the following manner: Section II tells about some existing methods. Then section III explains the proposed system. Section IV, section V and section VI deals with the performance analysis, results and conclusion respectively.

II. Existing Methods

There are many algorithms implemented for the research in face recognition. Algorithms such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Independent Component Analysis (IDA) were used in face recognition [10]. Linear Discriminant Analysis (LDA) performs dimensionality reduction "while preserving as much of the class discriminatory information as possible". Principal Component Analysis (PCA) uses orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. Independent component analysis (ICA) is a method for finding underlying factors or components from multivariate (multi-dimensional) statistical data. Local Histogram techniques were used to recognize the face [7]. The first fully automatic face identification system was developed by Kanade (as in [7]) using a set of facial facial parameters based on local histograms of gray scale pixel values. Local Binary Pattern is a type of feature extraction [7]. LBP is an efficient texture operator which labels the pixels of an image by thresholding the neighborhood of each pixel and considers the result as a binary number. Its main property is its robustness to monotonic gray-scale changes caused, for example, by illumination variations and computational simplicity. Global-based features of the face are taken rather than the component based features (local-based features).

Local-based features help in closer and also unique identification of a particular feature [7]. Geometric features are used to extract the local-based features. Geometric features may be generated by segments, perimeters [3]. It helps in closer identification of an object. The symmetry of the facial features such as eyes, nose and mouth region can be found for recognition. Another approach is to use Multiscale Distance Matrix (MDM). To recognize the face, first the closed boundary points of the face is required ie. closed shape [1]. This can be the base step to detect a particular global feature of the face over large number of faces in the database. Multiscale Distance Matrix approach utilizes the boundary points to recognize a particular shape. MDM technique is considered to be the fast approach when comparing with other algorithms [1]. MDM may use any of the distance metrics. One such is the Euclidean distance metric to find the distance between the given points. The input to the MDM is chosen to be the colour image from a particular colour space model. Authors Rein-Lien Hsu, Mohamed Abdel-Mottaleb and Anil K. Jain proposed the detection of face regions and face candidates in colour images by correcting the colour bias. This automatically estimates the reference white pixels [8]. Thus colour images are better in discriminating the features or objects in an image and also to distinguish them properly from the environment. T. Adamek and N.O'Connor worked with multi-level shape representation for single closed contour such as multi-scale convexity and concavity at different scale levels. The position and depth of both convexities and concavities are explicitly represented as desired and Dynamic Programming is used to match the two shape representations [6]. The authors S. Belogie, J. Malik and J. Puzicha worked with shape matching and recognition using shape context. For each point, shape context at a reference point captures the distribution of the remaining points relative to it, thus offering a globally discriminative characterization [9]. The shape context plays an important role of shape matching. The measurement of similarity is preceded by solving the correspondences between points on the two shapes and then using the correspondences to estimate an aligning transform. When the corresponding points on the two objects have the same shape contexts then it is considered to be similar. Shape context requires each and every point to be matched with the remaining points.

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III. PRPOPOSED SYSTEM

Two approaches such as shape representation and shape matching are taken for the work. First and second module extracts the shape of a face that is the global-based feature of the face using Multiscale Distance Matrix (MDM). Third module deals with the local-based feature using geometric approach. Geometric approach paves a way to identify the nearest face images closer to the input data given for testing.

The proposed work is split into three modules such as

A. Building up of the Distance Matrix based on the boundary of the face.
B. Finding the similar images from the MDM constructed.
C. Recognizing the facial features using the Geometric approach.

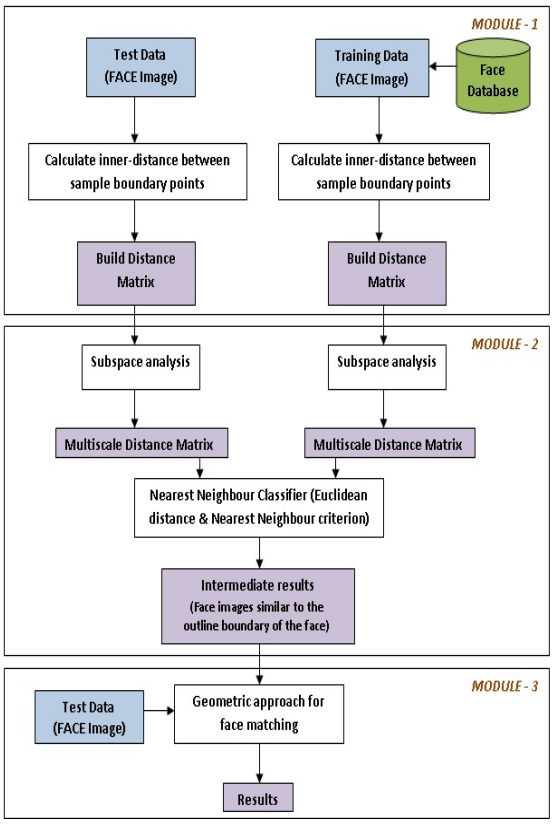

Fig.1. Architectural Diagram of the proposed system

Modules A and B are experimented and discussed in this paper. Module C is under work.

The input face image that is the test data is taken. Considering a number of sample points on the boundary of the input face image, the next step involves the computation of the inner distance between each and every considered sample points. From the inner distance values computed, build the distance matrix. Subspace analysis is done to remove the redundant values and the images from the database that are close to the input image are classified and again to filter those few images geometric characteristics is used and the result is produced. The architecture of the proposed system is shown in the fig.1.

A. Building up of the Distance Matrix

The input and output of this module is as follows.

Input : Test data
Output : Distance Matrix (DM)

Test data is the face image taken as input to test with the system built and training data are the images trained to build the model in the database. In this module, first the 'n' number of sample points on the contour that is the boundary of the face image is taken. For the work, 80 points were taken on the boundary of the face. The traced boundary of the face image is shown in fig.2. Then inner distance is calculated for each and every sample points considered. Inner Distance is defined as the length of the shortest path between two points within the shape boundary. The inner-distance is computed using any shortest path algorithm. Johnson's algorithm is used here to find the shortest path. Johnson's algorithm finds the shortest paths between all pairs of vertices in a sparse, edge weighted, directed graph. Shortest path between points can be found by developing a graph in which the nodes are the points and edges are the distances between them. There should be edge between two nodes if the points lie within the shape boundary. After computing the inner distance values between the sample points chosen, it is filled in the distance matrix. The diagonal entries in the distance matrix are all zeroes which are the distance between the point and itself. The output of this module is the distance matrix of order n x n is constructed.

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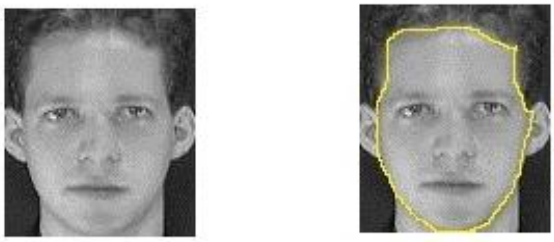

Fig.2. Traced boundary for the taking the points on the contour of the face.

B. Finding the similar images from the MDM constructed

The input and output of this module is shown below.

Input : Distance Matrix (DM)
Output : Similar shape of the face images

In this module, classifying the similar training samples (face images) based on the input test data is done. This is attained by subspace analysis followed by building up of the Multiscale distance matrix (MDM). Subspace analysis involves three steps such as,

a) In the matrix D, shift up circularly so that the first element becomes zero in each column (D_m).
b) Sort in ascending order in each row of the distance matrix (D_{ms}).
c) Remove the first and the last $\left\lfloor \frac{n-1}{2} \right\rfloor$ rows to remove the redundancy to construct the basic Multiscale Distance Matrix (MDM).

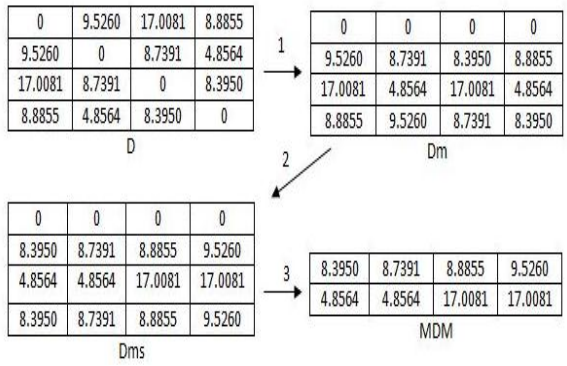

Fig.3. An example of MDM constructed. 1. Move up circularly 2. Sorting row in ascending order 3. Remove redundant rows

A sample of the MDM constructed is shown in fig.3. In the D_m matrix, first row are all zeroes which are the distances between the point and itself. The second row indicates the distance between the point and the points next to them. This procedure is followed for all the points. As we move down, each row captures coarser level of geometric properties until the row number reaches $\left\lfloor \frac{n}{2} \right\rfloor$. The second row of D_{ms} is same as the last row, both which indicates the distances between the points with an interval of 1. For this reason, half rows of the matrix D_{ms} are redundant and need to be removed. After removal of the redundant rows, the matrix obtained is called the Multiscale Distance Matrix (MDM). The MDM is constructed for the input image and also for all the images in the database. The similar facial shape images for the given input face image is classified using the nearest neighbour classifier such as the k-nearest neighbour algorithm.

k-nearest neighbour classifier is a method used to classify k closest training samples based on the input data given. Thus the output of this module results in the face images that are close to the input face image based on the shape of the facial boundary. These face images are considered as the intermediate result.

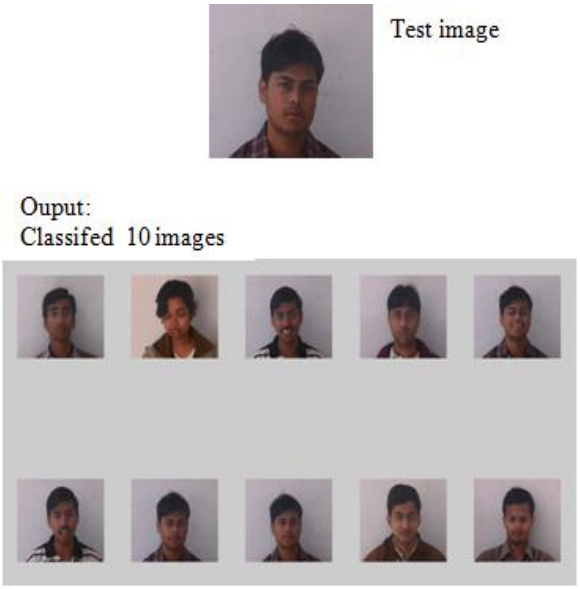

Fig.4. Images classified based on the test data (3 images that are of the same shape to the test data are classified)

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A. Recognizing the face using the closest approach using the Geometric approach)

The input and output this module is shown below.

Input: Similar shape face images
Output : Face image identical to the test data

The working of this module is to match the input face image to the face images obtained in the intermediate results. The similar face image among the 10 retrieved face images is matched using geometrical characteristics of the face.

Face geometry uses geometrical characteristics of the face. Many geometric features can be taken based on the sample points chosen. For the experiment, 37 points on the face image is taken. From the points, features are generated by means of segments, perimeters and the distance between two points. Euclidean distance metric is to be used to calculate the distance. The geometric features extract the local based features of the face to get the closest resemblance from the set of similar images. The output of this module is the face image of the person same as the input face image of the person taken.

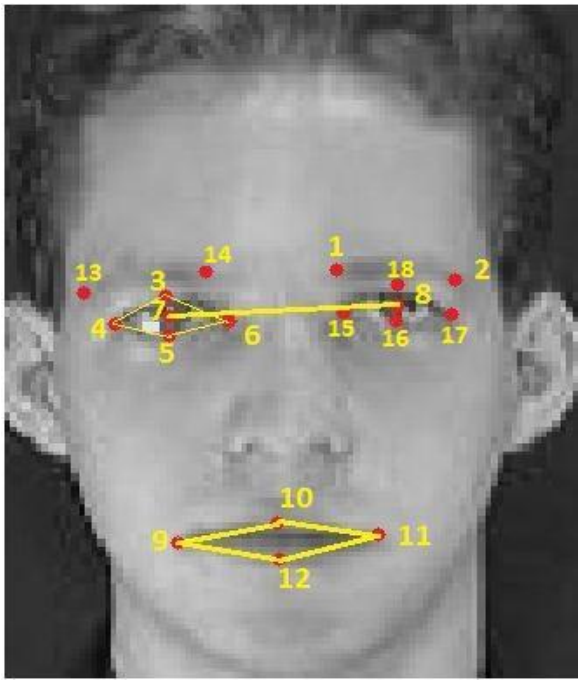

Fig.5. Geometric features of the face

In order to find the most nearest face image among the classified 10 images, geometric features of the face is taken. Fig.5. shows red dots referring to the points taken on the face image. For example, distance between the points 1 & 2, 7 & 8 are calculated. The points 9, 10, 11, 12 forming the perimeter of the lip region are also found. For the future work, 18 points on the face image is taken. 1 & 2 are the extreme end points of the eyebrows and same as for the other eyebrow. 9 & 11 refers to the extreme end points of the lips. Points 10 & 12 are the center points of the upper lip and the lower lip respectively. Points 9 & 11 indicate the extreme end points of the lips. These features help in closer identification of the face of a particular person among the classified face images.

IV. Performance Analysis

The datasets from AT & T Database and Indian Face Database are used. For the experiment 300 face images are taken for the training in which each person has three dissimilar face images. 100 face images of different persons were taken for testing. Results are correct for 80 classified images. For 80 test images out of the 100 test images, the retrieved results has at least one of the images of the same person from the database. Table I and table II shows the recognition rate based on the number of test images and the recognition rate based on the k value of the nearest neighbor classifier. From the table I, it is clear that 1 similar image to the test data were retrieved for 42 images. 2 similar images to the test data were received for 27 number of images and 3 similar training images were retrieved for 11 number of face images.

Table II shows the correct training images that are retrieved based on the value 'k' of the nearest neighbor classifier. For 100 test images as query (when k=10), 80 test images yields a correct output.

Table III shows the average precision rate based on the value of k. Precision also called as positive predictive value is the fraction of the retrieved instances that are relevant.

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TABLE I
Recognition rate based on the number of different test images.

Number of different test images	Number of training images relevant to the test data among the 10 retrieved
20	Nil
42	1
27	2
11	3

TABLE II
Recognition rate based on the k value of the nearest neighbor classifier

k-nearest neighbor value of 'k'	Number of training images for which at least one correct face image retrieved
3	45
5	58
10	80

TABLE III
Average precision rate based on the k value of the nearest neighbor classifier

k-nearest neighbor value of 'k'	Average precision rate (for 100 query images)
3	19.33
5	16.20
10	12.90

The local histogram (first fully automatic method) for face recognition had yielded a recognition rate of 75 percent [7]. The shape context approach had a retrieval rate of 76.57 percent [9] as compared to the MDM approach which has obtained a result of 80 percent. Other techniques are to be compared in the future work.

V. Results

MDM is a good technique in classifying face images of similar shapes. Inner Distance concept is used as a distance metric in the matrix instead of the Euclidean distance.

It does not require each and every point to be matched with all the other remaining sample points. Using nearest neighbour classifier we have retrieved nearest similar face images of 10 face images. It will be used to find the closest similar face image using geometric features. For the geometric approach, nearly 18 points are to be chosen to find the local-based feature of a particular face of the person. This helps in closer identification of the particular person based on the test data.

VI. Conclusion

The proposed approach for face recognition uses distance metric to represent the face shape. This approach is simple, robust and easy to implement since only a few parameters i.e., only the boundary points are used for the recognition of the face image. It is considered to be the fast approach since direct point-wise matching is not used to match the dataset. Half of the values in the matrix is removed for redundancy. Hence the remaining points are needed to match. Inner-distance is defined as the length of the shortest path between two points. Inner-distance captures shape better than Euclidean distance metric. Since inner distance is articulation insensitive and considers points only within the shape boundary. The contour points are taken on the boundary of the face image to extract its global feature.

One of the limitations is that the points on the boundary of the face image are assumed to be known. When some parts of the face is covered by hair, it is probably most difficult to yield a correct face image based on the query image. The experimental results may or may not be same if the face image has bad lightning conditions or illumination.

The MDM is constructed similarly for all the images in the database and checked with the test input image and obtained a result of 80 percent in the retrieval of images.

Acknowledgement

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