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Face Recognition Using Contour Matching

S. T. Gandhe, K. T. Talele, and A.G.Keskar

Abstract—In this paper a contour matching based face recognition system is proposed, which uses "contour" for identification of faces. The feasibility of using contour matching for human face identification is presented through experimental investigation. The advantage of using contour matching is that the structure of the face is strongly represented in its description along with its algorithmic and computational simplicity that makes it suitable for hardware implementation. The input contour is matched with registered contour using simple matching algorithms. The proposed algorithm is tested on BioID face database and % recognition rate is found to be 100%. The proposed system of face recognition may be applied in identification systems, document control and access control.

***Index Terms*—Face and gesture recognition, image processing and computer vision, pattern analysis, pattern recognition**

I. Introduction

Face recognition [1,2,3] is a form of biometric identification. A biometrics is "Automated methods of recognizing an individual based on their unique physical or behavioral characteristics." The process of facial recognition involves automated methods to determine identity, using facial features as essential elements of distinction. The automated methods of facial recognition, even though work very well, do not recognize subjects in the same manner as a human brain. The way we interact with other people is firmly based on our ability to recognize them. One of the main aspects of face identification is its robustness. Least obtrusive of all biometric measures a face recognition system would allow a user to be identified by simply walking past a surveillance camera[4,5]. The research on face recognition has been actively going on in the recent years because face recognition spans numerous fields and disciplines. There is an increasing demand for security in commercial and law enforcement applications. The rapid development of face recognition is due to a combination of factors such as active development of algorithms, the availability of large databases of facial images, and a method for evaluating the performance of face recognition algorithms.

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While humans quickly and easily recognize faces under variable situations or even after several years of separation, the problem of machine face recognition is still a highly challenging task in pattern recognition and computer vision. A face is inherently a 3D object illuminated by a variety of lighting sources from different directions and surrounded by arbitrary background objects. Therefore the appearance of a face varies tremendously when projected onto a 2D image. Different pose angles also cause significant changes in 2D appearance. Robust face recognition requires the ability to recognize identity despite such variations in appearance that the face can have in a scene. Simultaneously the system must be robust to typical image acquisition problems such as noise, video camera distortion, and image resolution.

The recognition methods are categorized as follows which is based on intensity images [6,7,8,9,10]:

Holistic matching methods use the whole face region as the raw input to a recognition system. One of the most widely used representations of the face region is eigen pictures [11,12,13,14,15,16], which are based on Principal Component Analysis (PCA). Using PCA, many face recognition techniques have been developed: eigenfaces, which use a nearest neighbor classifier; feature-line-based methods, which replace the point-to-point distance with the distance between a point and the feature line linking two stored sample points; Fisher faces which use linear/Fisher discriminant analysis (FLD/LDA); Bayesian methods, which use a probabilistic distance metric; and SVM methods, which use a support vector machine as the classifier. Utilizing higher order statistics, independent-component analysis (ICA) is argued to have more representative power than PCA, and hence may provide better recognition performance than PCA. Being able to offer potentially greater generalization through learning, neural networks/learning methods have also been applied to face recognition. One example is the Probabilistic Decision-Based Neural Network (PDBNN) method and the other is the evolution pursuit (EP) method.

In Feature-based matching methods, local features such as the eyes, nose, and mouth are first extracted and their locations and local statistics (geometric and/or appearance) are fed into a structural classifier. Earlier methods belong to the Feature-based matching methods, using the width of the head, the distances between the eyes and from the eyes to the mouth, etc, or the distances and angles between eye corners, mouth extrema, nostrils, and chin top. More recently, a mixture-distance based approach using manually extracted distances was reported. Without finding the exact locations of facial features, Hidden Markov Model (HMM) based methods use strips of pixels that cover the forehead, eye, nose, mouth, and chin reported better performance than by using the KL projection coefficients instead of the strips of raw pixels. One of the most successful systems in this category is the graph matching system, which is based on the Dynamic Link Architecture (DLA) Using an unsupervised learning method based on a self-organizing map (SOM), a system based on a conventional neural network (CNN) has been developed.

Hybrid methods are based on using both local features and the whole face region to recognize a face, as the human perception system uses. One can argue that these methods could potentially offer the better of the two types of methods.

In this paper human face identification system based on the contour matching is proposed. In this system first contour of a given image is taken and using simple matching technique the face is recognized. The proposed system is tested on a set of BioID face database [17] and % recognition rate is found to be 100%.

Section 2 describes the proposed system which is a three step process i.e. Image Processing and Normalization, Contour Generation, Matching Algorithm and section3 describe result and discussion and section 4 discusses conclusion.

II. PROPOSED SYSTEM

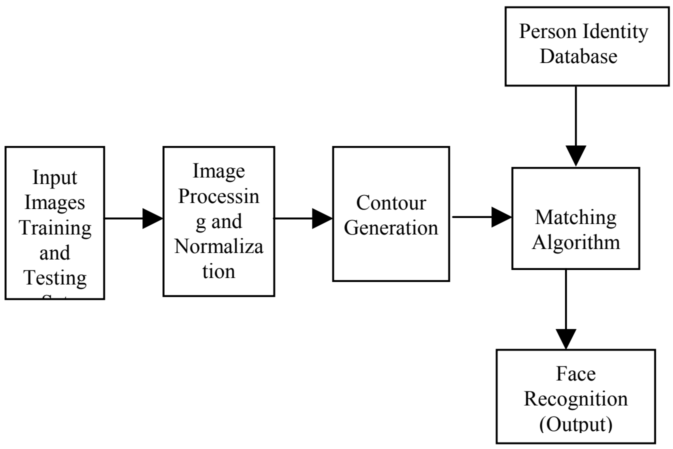


Figure 1: Block Diagram of Proposed System

The block diagram of face recognition system using Contour Matching is as shown in the Figure 1. It is a three step process i.e.

1) Image Processing and Normalization.
2) Contour Generation.
3) Matching Algorithm.

A. *Image Processing and Normalization*

The images are divided into two mutually exclusive sets: the training set and the test set. The training set is used to initialize and prepare the system to recognize arbitrary images and to fine tune the algorithm parameters. The test set is the set of images which is used to evaluate the performance of the system after training is completed. The images are preprocessed to improve the recognition performance. After the preprocessing stage, all the new images should have same dimension, so after cropping the face from the entire image, these new images are resized to 150 x 112 pixels. Another issue specific to faces, is that of facial expression, complexion and whether the subject is wearing glasses or has a moustache and/or a beard. The system should be able to identify faces whether they are smiling, sad, wearing glasses, not wearing glasses. Hence it is important to use a training face database that includes different images of same subject.

The images have to be preprocessed to make them suitable for recognition purposes. This generally consists of the following tasks:

1) Histogram Equalization: Histogram equalization is performed which enhances the contrast of images by transforming the values in an intensity image so that the histogram of the output image approximately matches a specified histogram as shown in Figure 2.

Figure 2: Image after Histogram Equalization

2) Noise Elimination: This is used to remove any noise (if present) from the image. This is done using gaussian blurring which is as shown in Figure 3.

Figure 3: Image after Gaussian Blurring

3) Normalization: This is used to compensate for any illumination variations or relative sizes between two sets of faces. This is done using pixel value normalization. In this stage the mean pixel value of all the pixels in the image is calculated. Also the standard deviation of pixel values is calculated. Using these values normalize the pixel values of the image by using the following formula

Pixel value normalized image = (Blurred image pixel -Pixel mean) / Standard deviation

B. *Contour Generation*

This is the core of the system in which the contour of a face is generated from the image. The whole face is treated as a contour map, with the areas of constant gray level brightness (i.e. the plains) enclosed by the contour lines. Thus contour lines for a given face can be generated. The contour of a given image is as shown in Figure 4.

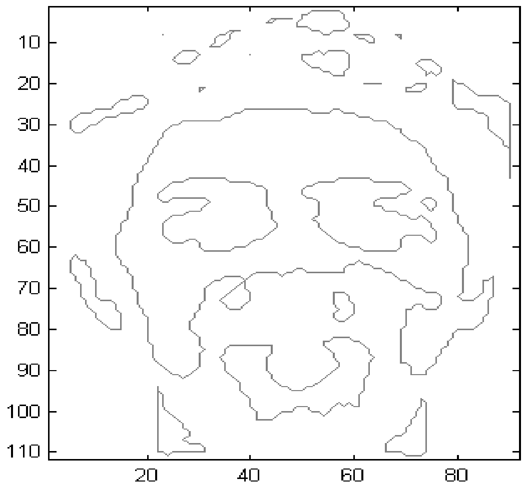


Figure 4: Contour of A Given Image

C. Matching Algorithm

In general, it is quite difficult to extract facial area information using only simple techniques. In two face images of the same person, similar features can still be found in their contours. On the contrary, there are remarkable differences, not only in the shape but also in the size of the contours for images of different persons. Hence, identification is done using the matching of contours of two faces. The picture which is to be matched is called the input picture, and the picture it has to be matched to is called the registered picture. Then contours are compared using template matching.

1) Calculation Of Matching Ratio

Calculation of matching ratio is a two step process:

i) Overlapping of input and registered contours.

ii) Fragment removal.

The steps of the matching algorithm is to find the matching ratio H(f,g) are as follows: To find maximum similarity between input and registered contour, the template matching technique is used. In this the input image is slid pixel by pixel across the registered image in a top to bottom and left to right fashion. If f(i,j) and g(k,l) are the pixels at position (i, j) and (k, l) of input and registered contour respectively, then α ,β measure the horizontal and vertical displacement between the two pixels f(i,j) and g(k,l) during the sliding process. To absorb the slight differences existing in the contour extracted from different pictures of the same person, a 5 x 5 window around a black pixel is used for template matching. If for a black pixel in the input contour there is another black pixel in the 5 x 5 neighborhood of the corresponding position on the registered contour, then the pixels are said to be matched. If $\hat{\alpha}, \hat{\beta}$ are the horizontal and vertical displacement respectively, which gives the best matching result, then the maximum similarity $h_{i.j}\left(\hat{\alpha}, \hat{\beta}\right)$ defined by equation 1 between corresponding contour is obtained [18].

$$h_{i.j}\left(\hat{\alpha}, \hat{\beta}\right) \stackrel{\Delta}{=} \max_{\alpha,\beta} \sum_{i.j} h_{i.j}\left(\alpha, \beta\right) \quad \text{-------------- (1)}$$

$$h_{i.j}\left(\alpha, \beta\right) = \phi\left[\sum_{x=-2}^{2} \sum_{y=-2}^{2} \left(f_{i.j} . g_{k+x,l+y}\right)\right] \quad \text{----- (2)}$$

$$k = i \pm \alpha,\ l = j \pm \beta,$$

$$\alpha = 0,1,2,\dots\dots\dots .149,\quad \beta = 0,1,2,\dots\dots,\ 111$$

$$\phi[x] = \begin{Bmatrix} 1 & for\ x \geq 1 \\ 0 & for\ x = 0 \end{Bmatrix}$$

For pictures of the same person, after template matching, long segments of overlapping (in the sense of equation 2) contour is obtained. On the other hand, for different persons, even if high matching ratio is obtained from equation 1 the existence of a great number of short segments overlapped by chance can be expected. Therefore, if these short segments can be eliminated effectively, a stable performance of the discrimination method can be achieved. The short segments are denoted as $S^{(n)}$ (n: a label for the segment, l: the length of the segment, θ_t: the threshold value for the segment length). Then the final matching ratio H(f ,g) can be calculated from equation 3[18].

$$H(f,g) = \frac{2}{F+G} \cdot \sum h_{i.j}(\hat{\alpha},\hat{\beta})$$

$$h_{i.j}(\hat{\alpha},\hat{\beta}) = 0\ if\ h_{i.j}(\hat{\alpha},\hat{\beta}) \in S^{(n)}(\ l \leq \theta_t) \quad \text{----------- (3)}$$

Figure 5: Contour of Given Image after Fragment Removal

F and G denote the number of pixels in the isodensity lines of the input and registered pictures respectively. The contour of a given image after fragment removal is as shown in Figure5. The fragment removal threshold (θ_t) and matching ratio threshold used for the identification/discrimination of the faces were determined by experimental means.

2) Calculation Of Fragment Removal Threshold

Ten sets of images were used to calculate fragment removal threshold. Each set had 5 images of same person with different expressions, which are taken from BioID face database.

The acceptance values of final matching ratio is calculated from equation 3 between different images of the same subject for different values of fragment removal threshold

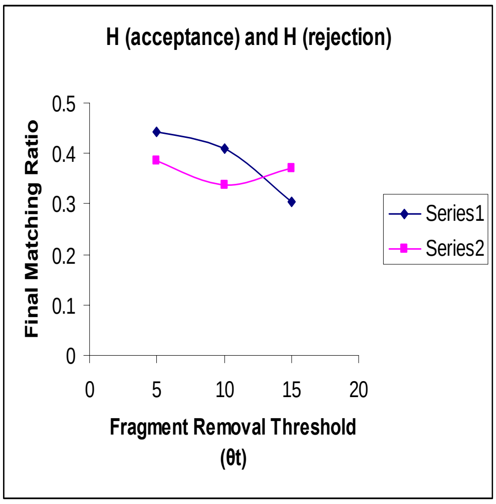
(θ_t) and take minimum acceptance value for a given threshold value called as H (acceptance).

The final matching ratio is also calculated from equation 3 between different subjects for different values of fragment removal threshold (θ_t) and take maximum of that value for a given threshold value called as H (rejection). Table1 shows different values of H (acceptance) and H (rejection) for different values of fragment removal threshold (θ_t).

Table 1: Final Matching Ratio Versus Fragment Removal Threshold (θ_t)

Final Matching Ratio \ θ_t	5	10	15
H (acceptance)	0.3862	0.3377	0.37
H (rejection)	0.4436	0.4084	0.3049

Using various samples of images optimum threshold is calculated. The final matching ratio, which is calculated after removal of fragments, is compared with the fragment removal threshold (θ_t) in this stage. Series 1 gives H (acceptance) and Series 2 gives H (rejection) and the graph is plotted between final matching ratio and fragment removal threshold (θ_t) values and chosen the fragment removal threshold (θ_t) value where H (acceptance) is maximum and H (rejection) is minimum which is as shown in Figure 6.



Final Matching Ratio	0.37
Fragment Removal Threshold	15

Figure 6: Selection of Fragment Removal Threshold

III. RESULT AND DISCUSSION

A Result Analysis Of Contour Matching

Table 2 gives comparative performance of Principal Component Analysis system[19,20] with Contour Matching system on BioID face database for 15 different subjects and there are 5 different images for each subject. So total there are 75 images. The Contour Matching system gives better % recognition rate. But the computational time is increased. Figure7shows number of training images versus % recognition rate .Initially first image in each subject is taken as a training image and test the proposed system. Some of the rejected images are added as training images and test the rejected images. For total 18 number of training images % recognition rate is found to be 100%.

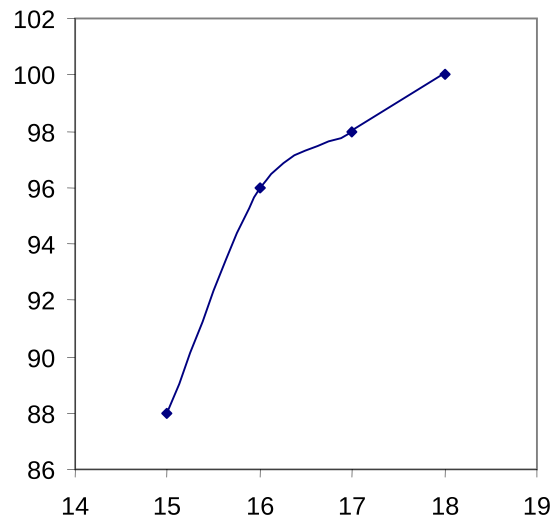


Figure 7: % Recognition Rate versus Number of Training Images

Table 2: Comparative Performance of Principal Component Analysis System with Contour Matching on BioId Face Database

Sr. No.	System	% Recognition Rate	Training Time Per Model	Test Time Per Image
1	Principal Component Analysis	95	6.52sec	2.73sec
2	Contour Matching	100	125.25 sec	302.59sec (Approx. 21min. after 50 images)

B Step By Step Output Of Contour Matching System

The experiments are done on two different input images, one is same as registered image and one is different from registered image. The sample outputs of these experiments are as follows.

1) Input image is same as registered image i.e. given image is in database. As given image is in database, therefore input image must be accepted. Figure 8 (a) and (b) shows registered image and input image. Figure 9 and Figure 10 shows images after histogram equalization and filtering of registered image and input image.

Figure 8: A) Registered Image B) Input Image

Figure 9: Registered Image And Input Image After Histogram Equalization

Figure 10: Registered Image and Input Image after Filtering

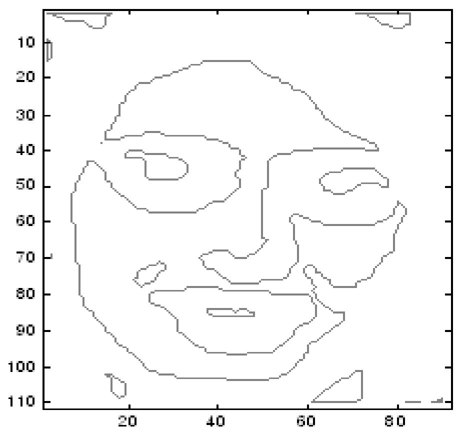


Figure 11: Contour of Registered Image

Figure 11 and Figure 12 shows contours of the registered image and input image

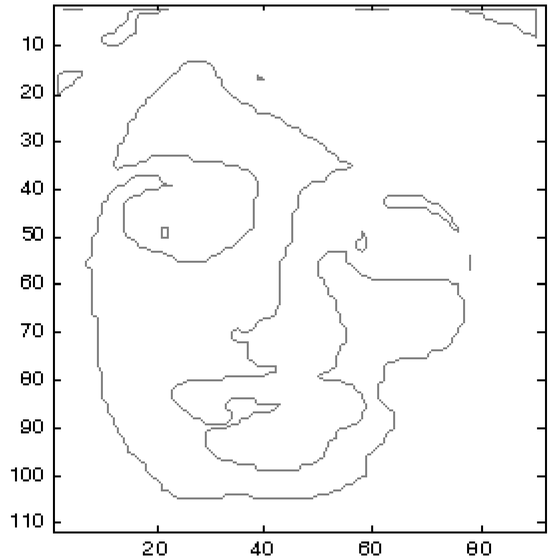


Figure 12: Contour of Input Image

Figure 13 shows the overlapped image. The input image is slid on registered image and using equation 1 and 2 the overlapped image is obtained. Figure 14 shows overlapped image after fragment removal using equation 3 and the acceptance ratio is found out. For acceptance this ratio must be greater.

Figure 13: Overlapped Image

Figure 14: Overlapped Image after Fragment Removal
Acceptance Ratio = 0.4454

2) Input image is different from registered image i.e. given image is not in the database. As given image is not in database, therefore input image is rejected. Figure 15 (a) and (b) shows registered image and input image. Figure 16 and Figure 17 shows images after histogram equalization and filtering of registered image and input image

Figure 15: (A) Registered Image (B) Input Image

Figure 16: Registered Image And Input Image After Histogram Equalization

Figure 17: Registered Image And Input Image After Filtering

Figure 18 and Figure 19 shows contours of the registered image and input image. Figure 20 shows the overlapped image. The input image is slid on registered image and using equation 1 and 2 the overlapped image is obtained. Figure 21 shows overlapped image after fragment removal using equation 3 and the rejection ratio is found out. For rejection this ratio must be less.

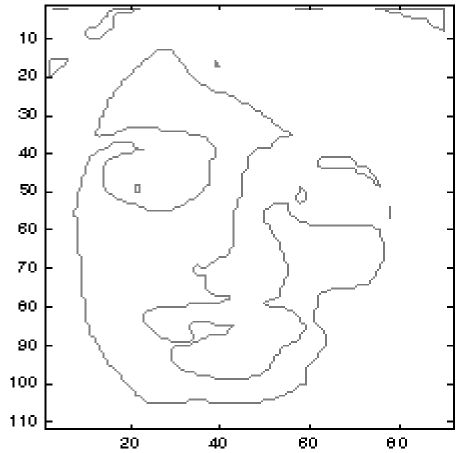


Figure 18: Contour of Registered Image

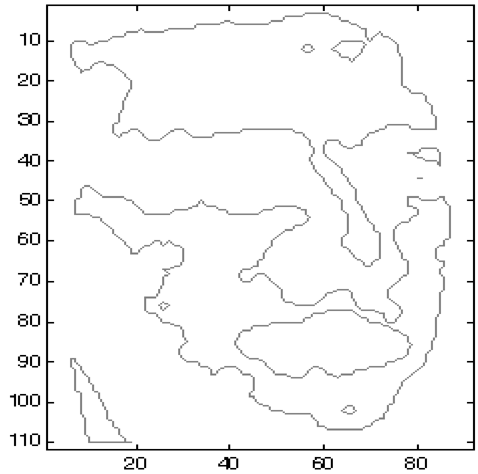


Figure 19: Contour of Input Image

Figure 20: Overlapped Image

Figure 21: Overlapped Image after Fragment Removal

Rejection Ratio = 0.2004

IV. CONCLUSION

Face recognition using contour matching has been proposed. The shape of the contours is affected by the tilting or panning of a face. Though the effect due to these are not examined. It is an important problem and is left open for later study. Some pictures used in the experiments did have a degree of panning or tilt in them but the angles were quite small. The matching results obtained show that with a small degree of panning and tilting, the results are quite good.

The further scope includes setting the threshold values automatically according to the characteristics of the image and experimentation with pictures with non-ideal faces or pictures taken by camera and the algorithm need to be tested for larger variation of database.

The proposed system of face recognition may be applied in identification systems, document control and access control. The face similarity meter was found to perform satisfactorily in adverse conditions of exposure, illumination and contrast variations, and face pose. Biometric technologies are found application in four broad application categories: surveillance, screening, enrollment identification, and identity verification.

General security tasks, such as access control to buildings, can be accomplished by a face recognition system. Banking operations and credit card transactions could also be verified by matching the image encoded in the magnetic strip of the card with the person using the card at any time. Finally, a robust system could be used to index video-documents (video-mail messages, for example) and image archives indexed in such a way would be useful for criminal identification by the investigation department.

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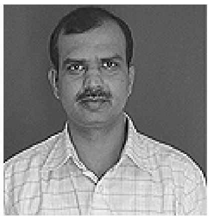

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