Multiple Media Based Face Recognition in Unconstrained Environments Using Eigenfaces

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***Abstract*— Face recognition is a challenging problem in computer vision and image processing domain and it is because of its numerous applications including video surveillance, Remote System logon, and Passport verification and so on. Among them face recognition is most important in Law Enforcement and Security area because of its unconstrained nature. Unconstrained Face Recognition differs from normal face recognition by the way it deals with the images and it uses images that are captured without target's co-operation. In a city crime including robbery, murder etc. the available sources to find the suspect are images or videos taken by the common people using their cell phones, Surveillance video frames at the public places or some sort of verbal descriptions provided by the eye witness. Using these verbal descriptions a photo sketch can be developed and can be used as a source of information regarding the suspect. So, the survey on Unconstrained Face Recognition reveals that all the available image sources can contribute a better identity to the target suspect. Thus this paper aims to train an automatic face recognition system that takes multiple media sources as inputs to recognize a person of interest from gallery of images using Principle Component Analysis.**

***Index Terms*— Unconstrained Face Recognition; Law Enforcement and Security; Multiple Media; Still face image; Video track; Face sketch; PCA**

I. INTRODUCTION

Although this work is all about Face Recognition (FR), one should basically know about Automatic Biometric Identification system. We can define it as a system that is able to establish the identity for a particular person from a large set of persons using some characteristic features of him/her known as Biometric features say for e.g. Face image, Fingerprint, Iris image etc. Unlike iris scanning, which can be demonstrated at a particular distance with active participation of subject, FR gives identification results within many meters with or without requiring subject's co-operation. So, among all automatic biometric identification system FR is promising particularly in Law Enforcement and Security area [3]. Then a formal definition for face recognition is that it is the process of establishing a unique identity to a person using a face image and extracted facial characteristics. We humans perform face identification several times in a day very easily, but the machine recognition of faces in an image is a challenging topic. This paper aims to develop a system that is able to do this task with a view to the challenges associated with FR in Law Enforcement and Security area, because there the process is unconstrained in nature. And thereby defining the term in the title unconstrained; by unstrained it is meant that the face

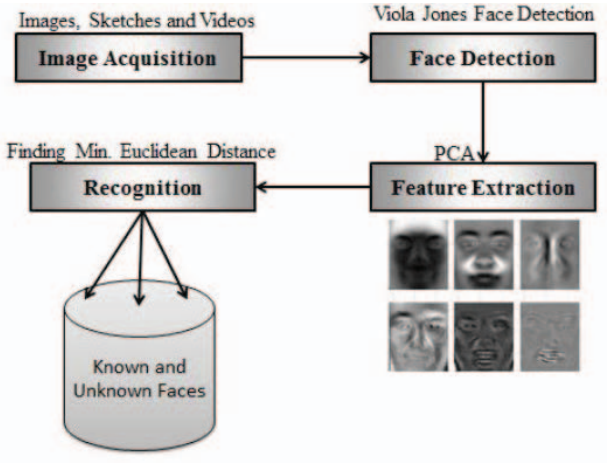

Fig. 1 Block Diagram of Proposed System

images shows variations in lighting, expressions, pose, camera quality etc. and also that faces are not captured by the exact co-operation of the target person [4]. So, Unconstrained Face Recognition (UFR) has to deal with such types of images and of course videos, because number of publicly available videos is increasing day by day. This is the area of interest of this paper; UFR in Law enforcements and Applications. A general block diagram that shows the process of Face Recognition is depicted below in Figure 1.

The first step of automatic face recognition is obviously the face detection which is a two class problem; after this step the faces in an image are separated from its background. The first framework for face detection is Viola-Jones face detection frame detection [15] and its mathematical manipulation is available in MALAB Computer Vision Toolbox. Using this we can detect the faces from the image. Once we separates the faces some sort of normalization is used to make the face image similar to that present in the gallery of images; say for e.g. images must be in similar dimension and resolution to get the better recognition accuracy. After normalization, some kind of facial features

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must be extracted to find the identity of the face image. There are different algorithms or methods to find the facial features in the image including LBP (Local Binary Patterns), LDP features etc. And one discussed most widely is Principle Component Analysis. One significant approach of feature extraction is Principle Component Analysis (PCA); by this method we get the statistical representation of the image. As the mathematical data can be manipulated very easily than other representations this method is effective. By this method we get the principle components in the image that is necessary for the description of image. The resulting image is known as eigenface representation of the images. The process is explained in detail in coming Section. And thereby we can recognize the person of interest.

Again the process of face recognition is aided with two sets of images; one is called gallery image set which is a named collection of images against which we are searching the identity of a person and other is called probe set of images of which we are establishing the identity. In Section II two such database are studied and are collected to do the work.

A survey on UFR is interesting [2] and by Section II the results of such a survey is discussed. After that the technical details of the work involving is presented (in Section III). By which the popular method for the face recognition is discussed i.e. PCA (Principle Component Analysis).

II. Survey Findings

UFR is aided with two widely discussed databases known as Labeled Faces in Wild (LFW) [6]; LFW is a collection of labelled face images of popular persons across the world and a video database called YouTube Faces (YTF) [5]; it is a collection of videos of known persons that are all downloaded from YouTube. The face images in YTF are subset of persons in LFW database. The study on existing UFR shows that FR in Law Enforcement and Security area is challenging because of the nature of sources of images available in this area. It is challenging because of lighting, distance, pose variations etc...(Figure 2). The available sources of information to prove the identity in the area are low quality images, videos taken by the bystanders using their own mobile phones and some verbal descriptions provided by them. Using these verbal description experts can develop a face sketch and this also can be evidence to aid recognition process. So apart from face recognition using single media as input, which may not provide sufficient information to recognize the person of interest, all available media can boost the accuracy of identification.

Fig. 2. Challenging (a) Face Images from LFW (b) Video tracks from YTF

Fig. 3.Media Collection for a target person.

But such a system of face recognition utilizing multiple media as input to recognize a person is new to the era of technology. But some theoretical explanation and one framework are available. In [1] they showed for the first time how multiple media can input to the system of face recognition. And the results are amazing; rank of retrieval can be increased using collection of media such as one or more images, one or more video tracks, and a 3D face model developed from 2D face images of varying pose or a face sketch. The media are incrementally added to the system to make a match and at the end we will have single candidate that matches the probe image. Thus media collection can trusted to give a better identification rate on an average. But the work is conducted with the help of COTS face matcher which is a frame work for the identification which cannot be utilized for normal applications and experimental study. And so, utilizing this idea, after the survey, this work aims to train a system that is capable utilizing multiple media of a person as input to recognize a person. The collection of media used in this work is images, videos, and a face sketch. Figure 3 shows a media collection for a particular person. First use the image to run the recognition algorithm. Analyze the top matches. If the returned result doesn't contain the intended person of interest use the next media to run the algorithm and it also returns

some matches and the results are compared against previously returned result for the first media. Repeat the step until a match is found or we have another media for the person to be identified.

III. METHODS AND DESCRIPTIONS

As mentioned above the steps involved in UFR is:

A. *Face Detection*
B. *Face Normalization*
C. *Feature Extraction*
D. *Recognition*

A. Face Detection

In this paper also Viola-Jones Face Detection Framework is employed. The work is done in MATLAB R2013a and in Computer Vision Toolbox of MATLAB we have a method to implement this task namely vision.CascadeObjectDetector. Utilizing this facility faces in an image can be separated from the background. It is because the images in the LFW dataset and faces in YTF video tracks are proved to be identified by the same framework.

B. Face Normalizations

By this step all image faces are converted to same size and resolution (each of size 250×250) in order to find the best match. The gallery images and the probe images are all normalized to faces with same resolution.

C. Feature Extraction

In order to recognize a person some facial characteristics must be extracted from the faces; this can be achieved by several techniques including LBP, LDP ICA etc. In this work we are using PCA for the recognition. This method extracts statistical features from the images. Step by step procedure is given below.

- Collect some training images; represent them as points on the vector space; this will reduce the dimension of analysis.

$$T = \{\Gamma_1, \Gamma_2, \Gamma_3 \dots\dots, \Gamma_n\} \quad (1)$$

- Subtract the mean Ψ from each image:

$$\psi = \frac{1}{M}\sum_{n=1}^{M}\Gamma_n \quad (2)$$

$$\Phi_i = \Gamma_i - \psi \quad (3)$$

- Calculate the eigenvectors and eigenvalues of the covariance matrix (C).

$$C = \sum_{n=1}^{M}\Phi_n\Phi_n^T \quad (4)$$

- Choose the principal components; Sort the Eigen values in descending order. The number of principle components k is determined arbitrarily by setting a threshold on the total variance (V).

$$V = n * (\lambda_1, \lambda_2, + \cdots + \lambda_n) \quad (5)$$

- Find k the smallest number satisfies:

$$\frac{n*(\lambda_1, \lambda_2, + \cdots + \lambda_k)}{V} > \varepsilon \quad (6)$$

- Eigen Vectors **v** of this matrix can be used to generate Eigen faces **u**:

$$u_k = \sum_{k=1}^{M} v_k \Phi_k \quad (7)$$

Each eigenvector has the same dimensionality (number of components) as the original images, and thus can itself be seen as an image. The eigenvectors of this covariance matrix are therefore called eigenface. They are the directions in which the images differ from the mean image. Eigen vectors determine the linear combinations of images in the gallery to form eigenface **u**. Figure 4 shows sample eigenfaces.

Fig. 4. Sample Eigenfaces

D. Recognition

To recognize a new face project it on to the face space spanned by these Eigen faces; there by representing the new face by a weighted vector consisting of weight of k Eigen faces.

$$w_k = u_k^T (\Gamma - \psi) \quad (8)$$

$$\Omega^T = [w_1 w_2, w_3, \dots] \quad (9)$$

This provides a set of weights describing the probe face. These weights are then classified against all weights in the gallery set to find the closest match. A nearest neighbor method is a simple approach for finding the Euclidean Distance between two vectors, where the minimum can be classified as the closest subject

$$\varepsilon_k = \|\Omega - \Omega_k\| \quad (10)$$

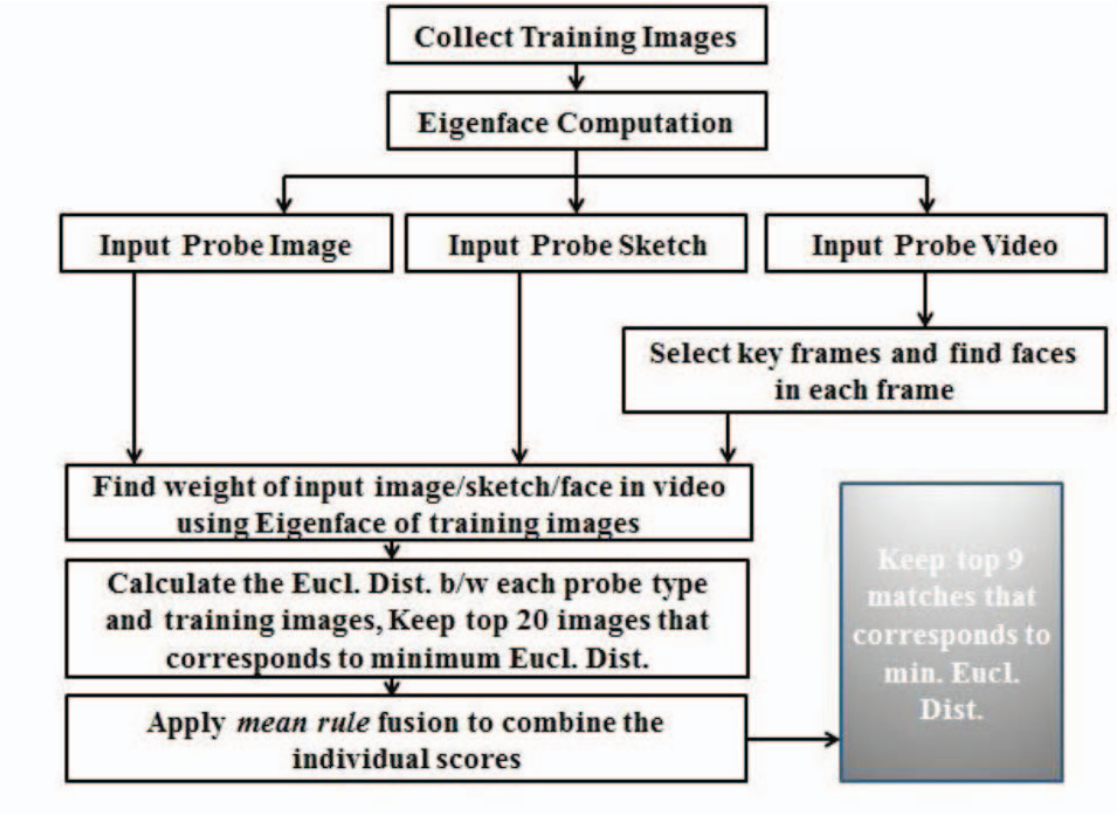

Fig.5. Flowchart Showing eigenface-based facial recognition using multiple media

IV. Experiments and Results

Figure 5 shows flowchart of functioning of multiple media based eigenface facial recognition system. For each image in the gallery 4 images with slight variation in pose and illumination are selected for training. That is if M=75 then 300 images are used for training. Find the eigenfaces for each training image and represent its weights. First input the probe image and find its weight based on eigenface and weights of the gallery images. Find the Euclidean distance between input probe image and gallery images. Keep only 20 images that correspond to minimum Euclidean Distance. Repeat this for probe sketch also. Then input the video of the probe subject. The video may consists of several duplicate frames so we have to avoid them. For the same a frame selection algorithm is used. In that a statistical threshold is set based on the histogram difference of every adjacent two frames. Then the frames are selected if the histogram difference of adjacent frames is greater than this threshold. Then the recognition is restricted to these frames only. From each image faces are detected, then represents it as a weight using eigenfaces of gallery images.

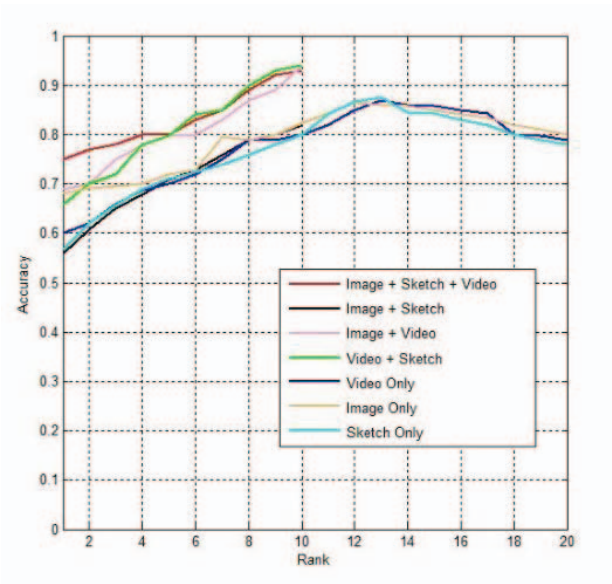

Fig. 6. Results

For each detected face finding top 20 matches are retained that satisfied minimum Euclidean Distance between its own weight and gallery image's weights. From all selected frames this process is repeated and finally only 20 images are finding as a result of video processing. A refined gallery is designed using *sum rule or mean rule* fusion of individual media result. These two outperforms equally than other fusion of scores such as *min*, *max* etc. So, now we have 60 images total from

each probe media. From that space we are selecting top 9 images that correspond to minimum Euclidean Distance. One of them shows the required match for the probe face.

The results are amazing. Fig.6. shows the results. It can be seen that the recognition from multiple media is effective than their single instances. By combining image sources the probability of getting the correct match increases. Among single media, video is performed well since some frames shows frontal face of the image. By selecting good frames recognition rate can be increased. Using three media we can achieve the correct match in top 9 matches. The Rank 1 recognition is still challenging due to the variation in images. Some images show Rank 1 recognition. Results are plotted in various cases. The result is plotted Rank vs. Accuracy. Seven plots are shown in figure such as plot showing single image only matching, single sketch , single video track, then combining image and sketch, image and video, sketch and video and finally combining all three media sources. It can be seen that combining media sources can improve the recognition rate. Combination of two media and three media results in recognition of a person within Rank 9. 70% images show Rank 1 recognition rate in the tested gallery. It is significant that recognition using image is successful but only within the Rank 20. In order to increase the recognition accuracy we employed the recognition with other sources of information of the person of interest. By combining two results the person is identified in among Rank 9.

In the testing phase first round test is conducted using images only. Inputting image one by one for each person and matched against the gallery of 300 images. Matching is performed using above mentioned PCA. The results are plotted as Rank within 20 and recognition accuracy. The same process is repeated for all collected face sketches of these persons and results are plotted. Again similar process is repeated for video tracks also only after applying the key frame selection algorithm. Among them image and video shows nearly equal results. After analyzing these results second round of testing is performed on two set of media; image and video, image and sketch and video and sketch. In which 94% persons were identified by image and video combination within Rank 9. Finally similar recognition rate is found by the combination of three media.

Recognition from Rank 1 varies because of the fact the images are taken without any cooperation of the subject or because of the photos are taken at a distance using some surveillance cameras or the photos are cropped from such video tracks. This is challenge in face recognition in Forensic area. This challenge can be met by combining available media source about the person under evaluation. Thus it is a major problem to address in the area of FRT; more and more progress must be made on algorithms to implement this idea and also if more media source such as a 3D model is available accuracy can be promised.

V. Conclusion

The paper discussed about a new idea of face recognition based on multiple media of a target person. In forensic and security like area FRT faces several challenges in identifying the suspect still now. To reduce this challenge FRT can be employed with suspect's all available media information. This topic in real time accomplished only with the help of a framework of recognition. So, the algorithmic approach of multiple media based face recognition is interesting and studied. As per the current study the identification accuracy is appreciable with the help of image, video tracks, and face sketch. If we can include another medium such as a 3D face model even more identification rate can be achieved.

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