EMERGING FORENSIC FACE MATCHING TECHNOLOGY TO APPREHEND CRIMINALS: A SURVEY

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ABSTRACT
To determine the identity of criminals, progress in biometric technology has provided law enforcement agencies additional tools. However, many crimes occur where none of the information is present, but instead an eyewitness account of the crime is available. In these circumstances, a forensic artist is often used to work with the witness in order to draw a sketch that depicts the facial appearance of the culprit according to the verbal description. Once the sketch image of the transgressor is complete, it is then disseminated to law enforcement officers and media outlets with the hopes of someone knowing the suspect. These sketches are known as forensic sketches. Criminal face detection and matching is a forensic technique that has been routinely used in criminal investigation. So there is an urgent need for integration of sketch matching system which can fulfill the requirement of legal systems. With the rapid increase in the number of surveillance cameras and mobile devices with built in cameras, the forensic world is changing, and the progress in face matching is help to lead the way. This paper provides an up-to-date critical survey of still- and video-based face matching research. To provide a comprehensive survey, not only categorize existing matching techniques but also present detailed descriptions of representative methods within each category. In addition, relevant topics such as issues of illumination and pose variation are covered.

KEYWORDS: *Forensic pose and expression, forensic sketch, face recognition, face matching, mug shot gallery*

I. INTRODUCTION

Forensic sketch matching is one of the most important task forensic examiners carry out manually during their investigation when there is a video or image available from crime scene. Forensic examiners perform manual examination of facial images or videos for a match with huge database of mugshots. The use of automated system aimed at facial recognition will not only improve the efficiency of forensic work performed by various law enforcement agencies but will also standardize the comparison process[1][2]. Although biometric face recognition has been used for secure building access, border control, Civil ID and login verification, however, there is no such system exists which can be used for identification or verification in crime investigation such as comparison of images taken by CCTV with available database of mugshots.

First, the consequences of a wrong decision made by forensic face recognition are far severe from biometric face recognition. The reason has been the enormous variability both in faces such as pose, lighting conditions, facial expression as well as in imaging systems itself such as image quality, resolution and compression[1][4]. Finally it should be mentioned that in forensic scenario the quality of images available for processing is generally low such as images of crime scene from CCTV[5]. Such images are usually of low resolution as well as unrestricted pose and sometimes even images of half occluded faces. However, recognition task in forensic framework is "offline" in contrast to

biometric system where a decision is to be made in real-time, e.g., user access system at a building or border control scenario.

In this paper, we review existing literature on forensic sketch matching with database. Where a paper is pure theoretical description, a short summary is presented. For experimental works, overall conclusions and results are discussed. There are only a few papers focusing on forensic application of face recognition mainly because more effort is done on the improvement of technology itself rather than its application. However, as the performance of face matching system improves there is a great need for integration of technology with legal system and a uniform framework for application of face recognition technology in forensics[15][17].

The rest of the paper is organized as follows: In section 2, we discuss the techniques and methodologies used by forensic examiners for purpose of facial comparison. Section 3 presents a literature review of forensic sketch matching with mug shot photo gallery. In section 4 present conclusions and some future research directions in forensic sketch matching domain.

II. DETECTING FORENSIC FACES IN A SINGLE IMAGE

Single image detection methods can be classify into four categories; some methods clearly overlap category boundaries and are discussed in some papers[15][16][19].

Knowledge-based methods: This method encode what constitutes a typical face , example the relationship between facial features. That is this method is rule-based methods which encode human features of face. Usually, the rules capture the relationships between facial features. These methods are designed mainly for face localization.

Feature invariant approaches: The main aim of this algorithm is used to find structural features that exist even when the pose, viewpoint, or lighting conditions vary, and then use these to locate faces. These methods are designed mainly for face localization[2].

Template matching methods: Several standard patterns of a face are stored to describe the face as a whole or the facial features separately. The correlations between an input image and the stored patterns are computed for detection. These methods have been used for both face localization and detection.

Appearance-based methods: In contrast to template matching, the models (or templates) are learned from a set of training images which should capture the representative variability of facial appearance. These learned models are then used for detection. These methods are designed mainly for face detection.

2.1 Working Groups

There are several working groups active in this area whose aim is to standardize the procedure as well as the proper training of facial comparison experts. One of the best effort toward developing standards and guidelines for forensic facial identification is currently carried out by Facial Identification Scientific Working Group (FISWG) [6]. It works under Federal Bureau of Investigation (FBI) Biometric Center of Excellence (BCOE). FISWG focusing exclusively on facial identification and develop consensus, standards, guidelines, and best practices for facial comparison. Currently they have developed drafts of several useful documents in this regard which include a description of facial comparison, facial identification practitioner code of ethics, training the experts to perform facial comparison. These documents are available for public review and comments [6]. Some other workgroups active in developing standards and guidelines for forensic facial comparison includes International association for identification [7] and European network of forensic science institutes (ENFSI) [8]. The standardization of the process of facial comparison and specific guidelines which are agreed upon by forensic community is still an unsolved problem.

2.2 Manual Facial Comparison by the Forensic Expert

In this section we briefly review the forensic expert's way of facial comparison. The discussion is based on the guidelines set forward by the workgroup on face comparison at National Institute of criminology and forensic science (NICFS) [9]. The facial comparison is based on morphological-anthropological features. In most cases it is tried to obtain pictures to be in same posture. The comparison mainly focuses on: Shape of mouth, eyes, nose, ears etc, Relative distance among

different relevant features, Contour of cheek- and chin-lines and Lines, moles, wrinkles, and scars etc in face

When comparing faces manually, it should be noted that differences can be invisible due to underexposure, overexposure, resolution too low, out-of-focus and distortions in imaging process. Furthermore, similar features can result in different depictions due camera position compared to head, insufficient resolution, difference in focusing of two images, and distortion in imaging process.

Due to aforementioned effects which usually make the comparison process difficult, the anthropological facial features are visually compared and classified as: Similar in details, Similar, No observation, Different, Different in details. Apparent similarities and differences are further evaluated by classifying features as: weakly discriminating, moderately discriminating, and strongly discriminating. Conclusion based on this comparison process is a form of support for either of the hypothesis and can be stated as "no support", "limited support", "moderate support", "strong support", and "very strong support". The process is subjective to great extent and conclusion of one expert can be different than other[13].

There is a great need to automate the process since it will not only improve the speed of comparison but also it will help standardize the process.

III. LITERATURE REVIEW

In this section we briefly review existing literature on forensic face recognition. Our review is specifically focused on works which are discussing forensic aspects and applications of the technology in hand rather than techniques for biometric face recognition where there are already good surveys available

3.1. Performance Analysis of Face Matching and Retrieval in Forensic Applications [1]

Two different types of difficulties of face recognition technology in forensic applications are discussed in this paper: 1) face retrieval using various pose and expressions 2) matching forensic sketches to face photograph databases. To apprehend the criminals when no photos of suspect is available then solutions to these two difficulties are necessary for accurately remove the duplicates in various government databases, including passport, driver license photos. In order to solve the first problem for pose and expression, Wavelet Transform, Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) algorithms are used. The second problem is considered, where analysis and improvements are offered for matching forensic sketches against large mug shot galleries. Likewise this paper addresses the scenario in which man and machine plays a major role for successful face recognition.

To catch the criminals, this paper develop a system that can recognize faces with different challenges such as pose, expression, sketches where the treatment of face may fail to produce correct recognition. One of the image is compared with training image and finally, the person who receives minimum distance is chosen as the best match as shown in below figure 1.

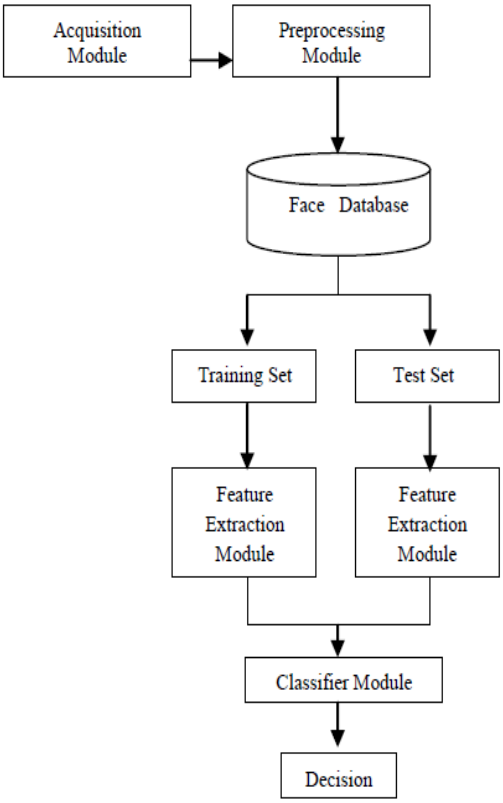

Fig.1: General steps in face recognition

To provide the perfect match Scale Invariant Feature Transform can also be used. When the number of training images increases the efficiency also increases. It is applicable for all three algorithms as mentioned in this paper. Comparison of these three algorithms shows that, LDA performs better than PCA and DWT since it directly deals with the class discriminants. But LDA also decreased with efficiency. So LDA is a further reduction technique of PCA.

3.2. Face Image Retrieval Based On Probe Sketch Using Sift Feature Descriptors [2]:

This paper addressed the solution to the problem is somewhat in between face recognition and image retrieval because sketches drawn with pencil has altogether a different modality in comparison with face photos. It highlights two interesting and related problems: similar visual feature extraction from sketches and photos, and comparing features of the sketch-photo pairs. This paper presents a feature-based method for matching facial sketch images to face photographs. Here descriptors are calculated at selected discrete points such as eyes, nose, ears etc. These features are well-suited for sketch-photo matching because they describe the distribution of the direction of edges in the face and also their combination with the geometric position of the annotated key points, which is the information common to both sketches and photos. This allows to compare only prominent features. This has distinctly two parts: Training and Test. Training starts with manually annotating key-points on the Training set of corresponding sketch-photo pairs. However Active Shape Model (ASM) can also be used to do automatically for a given probe sketch at the time of testing. ASM is a statistical model of the shape of object in training image which iteratively deform to fit to an object in a new image. It captures the natural variability within a class of shapes[12]. The model is built by learning the patterns of variability of annotated points of a training database. Fig.2 shows 41 key points annotated on sketch-photo pairs.

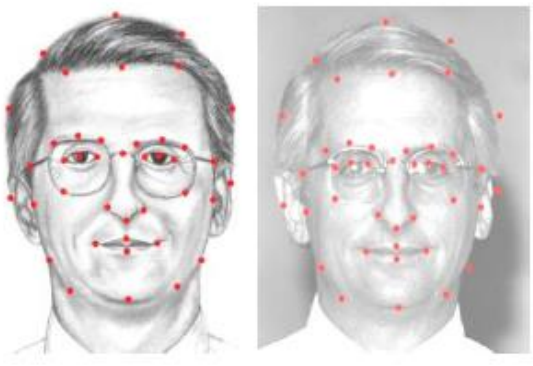

Fig.2 Annotated Points on corresponding sketch-photo pair from database

The proposed approach matches over 100 sketch –photo pairs in less than a minute with a good accuracy. The major contribution of this paper is fusion of linear and non-linear approaches i.e. annotated points and SIFT feature descriptors which makes real time matching of sketches with photos at low computational cost[12].

3.3. Matching Composite Sketches To Face Photos: A Component Base Approach [3] :

Unlike sketches hand drawn by artists, composite sketches are synthesized using one of the several facial composite software systems available to law enforcement agencies. To measure the similarity between a composite sketch and mugshot photograph this paper propose a component-based representation (CBR) approach as shown in figure 3. Specifically, automatically detect facial landmarks in composite sketches and face photos using an active shape model (ASM). Features are then extracted for each facial component using multiscale local binary patterns (MLBPs), and per component similarity is calculated[13][14][19]. Finally, the similarity scores obtained from individual facial components are fused together, yielding a similarity score between a composite sketch and a face photo. Matching performance is further improved by filtering the large gallery of mugshot images using gender information[11].

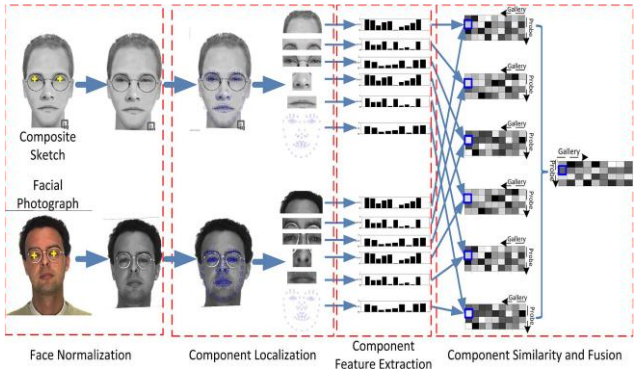

Fig. 3. Overview of the component-based representation approach for matching composite sketches to face photos.

This method significantly outperforms a state-of-the-art COTS face matcher. The performance of the proposed method is further improved by filtering the gallery set with gender information. These are applied for law enforcement. Analysis of the variations in the quality of composite sketches synthesized by two users of different ethnic and cultural background suggests that users of facial composite software should be trained to reduce the cross-race bias in order to create high quality composite sketches for potential suspects of various races. The second approach to sketch recognition attempts to learn or design feature representations that reduce the intraclass difference caused by modality gap while preserving interclass separability[11]. Representative methods in this category include common discriminant space, coupled spectral regression (CSR), coupled information-theoretic projection (CITP) and partial least squares (PLS)

3.4. Face Matching And Retrieval In Forensics Applications[4] :

This paper review forensic face recognition approaches and the challenges they face in improving matching and retrieval results as well as processing low quality images. This articles highlights the face recognition technology to forensic application. Author explain why forensic face recognition differ from typical portrait face recognition. A face recognition system is typically designed to output a measure of similarity between two face images. This also involves finding key facial landmarks like centre of the eyes for alignment and normalizing the face's appearance. Using the landmarks primary facial features are extracted and excluded in subsequent facial marks detection process. First, face image is mapped to the mean shape to simplify the subsequent process. Although the demonstrated performance of their proposed approach of facial marks detection is not robust, nevertheless, facial marks give a more descriptive representation of facial recognition accuracy compared to the numerical values obtained from traditional face recognition systems.
Therefore forensic face recognition often requires a pre-processing stage of image enhancement or specialized matcher to perform recognition. Hence with rapid increase in number of surveillance cameras, the forensic world is changing and the progress in face recognition is helping to lead the way.

3.5. Matching Forensic Sketches And Mug Shots To Apprehend Criminals [5]:

This paper gives emerging face recognition technology which can use forensic sketches to help identify criminal suspects. A new paradigm has emerged for identifying suspects using forensic sketches. A sketch can be converted to a digital image and then automatically matched against mug shots (arrestee photos) and other face images in a database—for example, drivers' license photos—to help make an identification. This automated approach, enabled by progress in computer vision and machine learning algorithms, offers a valuable resource to authorities seeking to accurately and quickly capture dangerous criminals. Law enforcement's need for a system that matches sketches to photos has prompted continued research to increase automatic face recognition accuracy. With a prototype automatic sketch recognition system soon to be deployed in the field, this technology will improve a process that has helped identify suspects for well over a century. Improving forensic sketch recognition requires a feature extractor and matcher specifically designed for this task. Proposed system first partitions sketch and face images into *N* slices. It then computes scale-invariant feature transform (SIFT) and multiscale local binary pattern (MLBP) descriptors for each slice, which remain stable between sketches and photos. Next, it uses local-feature-based discriminant analysis (LFDA) to extract the most salient features for each slice. Finally, the system measures the similarity between feature vectors to match sketches with photos.

IV. CONCLUSIONS AND FUTURE WORK

Although there is a lot of research going on focusing on the development of new techniques and methodologies to bring improvement in matching forensic face recognition systems performance. However, less effort is devoted to integrating sketch matching technology with legal system of court and justice. Forensic face matching is a technology in which there is a lot of research going on focusing on the development of new techniques and methodologies to bring improvement in current state-of-the-art face matching systems performance. The output of a biometric face recognition system is not suitable for use in forensic application and the output of conventional score based biometric system must be processed so that it is more useful and acceptable by the court. One of the important aspects of forensic face recognition system is they are not always successful in matching face due to challenge of variability of face. Therefore it can also be seen as few approaches for solving these problems in a computer vision. Also the technology of face recognition is reaching sufficient maturity for rapid growth in its application domain[14]. Beside a few papers much published as to how the sketch matching system can be adopted for forensic purpose. However hand-drawn face sketches are still very limited in terms of artists and number of sketches because after any incident a forensic artist prepares a victim's sketches on behalf of the description provided by an eyewitness. Sometimes suspects used special mask to hide some common features of faces like nose, eyes, lips, face-color etc. but the outliner features of face biometrics one could never hide. However some papers highlights the

challenges in matching forensic sketch technology for forensic application. There is an urgent need for tuning and integration of face recognition systems or development of new system which can fulfill the requirements of law enforcement agencies and legal system of court and justice. Continued efforts on matching forensic sketches are critical for assisting law enforcement agencies in apprehending suspects. A larger data set of forensic sketches and matching photographs needs to be collected to further understand the nature and complexity of the problem. One possible approach would be to build system which exactly mimics the forensic examiners way of facial comparison rather than the prevailing techniques in biometric domain[11].

Using a collection of 159 forensic sketches, we performed matching against a gallery populated with 10,159 mug shot images. Further improvements to the LFDA and MLBP methods will achieved by utilizing ancillary information such as gender and race to filter the 10,159 member gallery. SIFT descriptor represents both sketches and photos. We improved the accuracy of this presentation by applying an ensemble of discriminant classifiers. It will clearly perform better on a public domain – viewed sketch data set than previously published approaches.

So future work includes improving face detection and matching accuracy, and extending the automatic detection to off frontal face images

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