ISSN:0975-9646

Enhanced Holistic and Component Based Algorithm for Sketch to Photo Matching in Criminal Investigations

Chippy Thomas[#1], Dr. D. Loganathan[*2]

[#]*Final year M. Tech CSE, MET'S School of Engineering, Mala, Trissur, Kerala.*
[*]*HOD, [1]Department of CSE, MET'S School of Engineering, Mala, Trissur, Kerala.*

Abstract: **Sketch to Photo matching is an important research challenge. Main application of sketch to photo matching comes under criminal investigations. One of the important clues in solving crimes and apprehending criminals is matching facial composites with mug shots based on eyewitness memory. Sketches drawn based on eyewitness descriptions are posted in public places and media hopping that someone will recognize the suspect and provide information's leading to arrest. This method is very useful and many criminals are captured by this way. But this method of identifying is slow and tedious and it does not using the available large resource of low enforcement agency. Low enforcement agency maintains mug shot gallery. Mug shot gallery contains photographs of criminals who were arrested. There exist some systems that matches sketch with mug shots. In this paper, explains a new idea for matching sketch with photos. This method provides more matching accuracy.**

Keywords: **Facial composites, Mug shots, Hand-drawn composite, Software generated composite, Surveillance composite.**

I. INTRODUCTION

Biometrics is one of unique ways of identifying a person by physiological features in human body. If a fingerprint is found at the crime scene or surveillance camera captures image of suspect, then these can be used to identify suspect using biometric recognition methods. But in many cases these information's are not available. But there will be eyewitness who had seen suspect. Sketches or facial composites are widely used by law enforcement agencies for the identification of suspects involved in criminal activities. Sketches are particularly valuable when eyewitness is the only evidence available. Sketch is drawn based on witness description by forensic artist or by software. Sketch used in law enforcement agency can be divided into three categories.

A. Hand-Drawn Composites

Hand-drawn composite is drawn by forensic artist with special training based on descriptions provided by either one or multiple witnesses. Figure 1 shows example of hand-drawn composite and corresponding mug shot mate.

B. Software-Generated Composites

Software generated composites are created using menu driven software kits based on description provided by witness. Widely used software systems are FACES, Identi-Kit.IN most composite software, operator select from a set of facial components to create a face. Figure 2 shows example of Software-generated composite and corresponding mug shot mate.

C. Surveillance Composites

Surveillance composite are drawn by forensic artists based on poor quality surveillance images. Such as image captured by cell phones, retail surveillance camera, and ATM cameras. To make the use of these poor quality images, low enforcement agencies often employ a forensic artist to create high quality sketch from low quality surveillance images. Figure 3: Example of surveillance composite and corresponding mug shot mate.

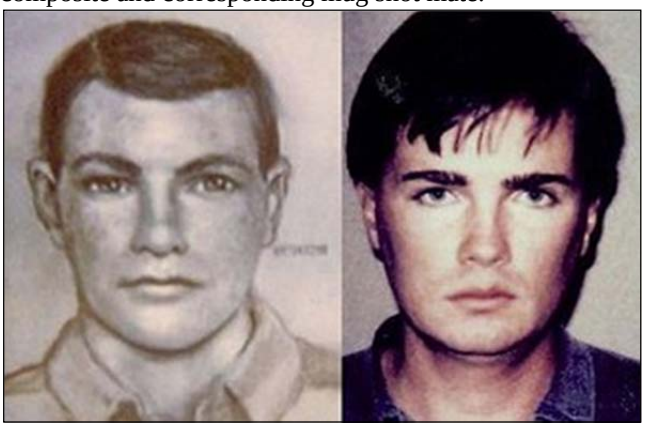

Figure 1: Example of Hand-drawn composite and corresponding mug shot mate.

The quality of composite depends upon skills of artist and accuracy of description provided by witness. A mug shot is a photographic portrait typically taken after a person is arrested. A typical mug shot is two-part, with one side-view photo, and one front-view. The background is usually stark and simple, to avoid distraction from the facial image. There are several methods that match sketch with mug shots. From these only few methods have been published for automatic matching. In these reported methods with the exception of [7], composite were created by operator was viewing high quality mug shot. This type of composite has no use in criminal investigation. Because no need to create composite if we had photo of suspect. Matching sketch with mug shot can't be done directly.

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Figure 2: Example of Software-generated composite and corresponding mug shot mate.

Figure 3: Example of surveillance composite and corresponding mug shot mate.

This paper deals with reviews on various sketches to mug shot matching methods. The rest of the paper is organized as follows: section 2 presents outline to sketch to mug shot matching process. In section 3, briefly review the previous research that has been conducted in sketch to mug shot matching. In section 4 presents FaceSketchID system method. Section 5 describes the enhanced FaceSketchID system and then section 6 present conclusions.

II. Sketch to Mug shot Matching Process

For identifying suspects involved in criminal activities, law enforcement agency uses sketches when there is no photo of suspect is available. Sketch used for this purpose are hand-drawn sketches, composite sketches and surveillance sketches. Viewed sketches are used for this purpose because, if we have photo of criminal then there is no need of sketch matching. From one witness or from more than one witness descriptions are analyzed. There are some difficulties in generating accurate sketch.

- Inaccurate description provided by witness.
  Sketches are drawn from human memory. So it may lead to inaccurate description of the suspect.
- The time difference between mug shot was taken and when witness has seen victim.
- Different image modalities
  It's difficult to compare a composite to a mug shot in terms of pixel intensities.
- Variability in artist's skill.
- Limitations of composite software.

There is a large gallery of mug shot database maintained at law enforcement agency. Most methods use this mug shot database for sketch to mug shot matching. Sketch is input to sketch to mug shot matching system. Forensic sketch, composite sketch and surveillance sketches can be used here. Sketch to mug shot matching system uses various techniques to compare sketch with mug shot gallery. Most matched mug shot or mug shot with minimum mismatch is displayed as result. Figure 4, shows the outline of sketch to mug shot matching.

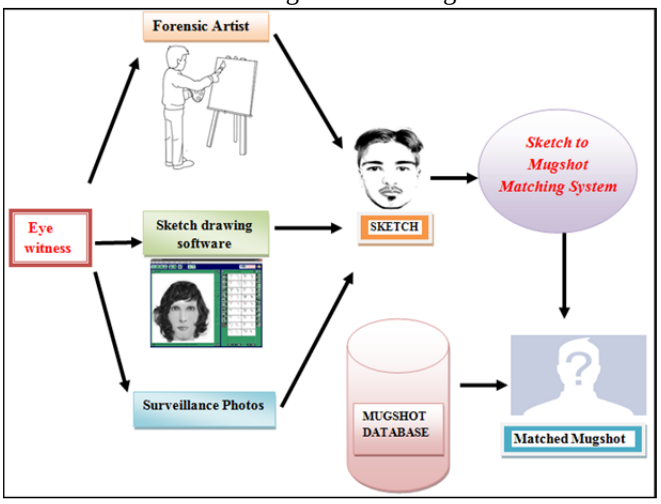

Figure 4: Overview of Sketch to Mug shot matching.

III. Literature Survey

There are various papers which explain about sketch to mug shot matching. Each of these uses different techniques. Of these, most papers focusing on hand drawn composite only. There are some papers focusing on software generated composites and surveillance composites. Sketch recognition algorithms can be classified into two categories. They are generative approach and discriminative approach. Generative approaches model a digital image in terms of sketch or vice versa and then match it with the query sketch. Discriminative approaches perform feature extraction and matching using the given digital image and sketch pair and do not generate the corresponding digital image from sketch or the sketch from digital image.

A. Generative Approaches

This paper [10] proposes a novel face photo-sketch synthesis and recognition method using a multi-scale Markov Random Fields (MRF) model. This system has three components. 1) Given a face photo, synthesizing a sketch drawing; 2) Given a face sketch drawing, synthesizing a photo; and 3) Searching for face photos in the database based on a query sketch drawn by an artist. It has useful applications for both digital entertainment and law enforcement.

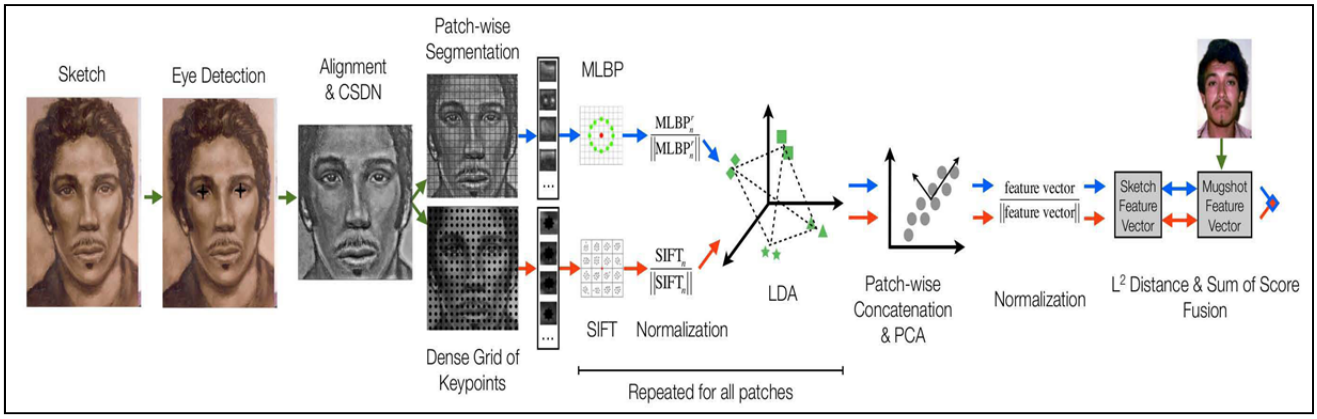

Figure 5. The Holistic Algorithm

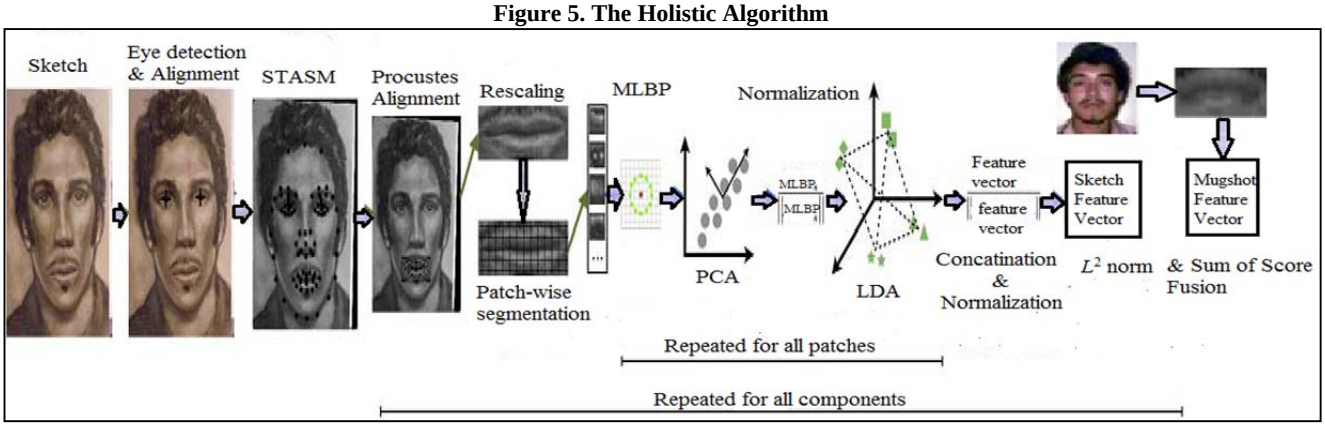

Figure 6. Component Based Algorithm

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To synthesize sketch/photo images, the face region is divided into overlapping patches for learning. The size of the patches decides the scale of local face structures to be learned. By transforming a face photo to a sketch (or transforming a sketch to a photo), the difference between photos and sketches is significantly reduced and thus effective matching between the two in face sketch recognition can be done. Experiments are conducted on a face sketch database including 606 faces.In [9], an automatic sketch synthesis algorithm is proposed based on embedded hidden Markov model (E-HMM) and selective ensemble strategy. First, the E-HMM is adopted to model the nonlinear relationship between a sketch and its corresponding photo. Then based on several learned models, a series of pseudo-sketches are generated for a given photo. Finally, these pseudo-sketches are fused together with selective ensemble strategy to synthesize a finer face pseudo-sketch.

In [8] this approach proposes the opposite of above described methods because that methods covert photo into sketch. Sketch images have less information compared to original face image. So by transforming all face images into their sketch, we lose information which may be useful for the recognition phase. This paper generating a face image from the composite sketch using a hybrid subspace method and then build an illumination tolerant correlation filter which can recognize the person under different illumination variations from a surveillance video footage. It uses CMU PIE (pose illumination and expression) database.

B. Discriminative Approaches

In [1], using a robust feature based method LFDA forensic sketch to mug shot matching is performed. In LFDA, individually represents sketches and photos using SIFT feature descriptors and multiscale local binary patterns (MLBP). Multiple discriminant projections are then used on partitioned vectors of the feature-based representation for minimum distance matching. This method to matches a data set of 159 forensic sketches against a mug shot gallery containing 10,159 images. LFDA offers substantial improvements in matching forensic sketches to the corresponding face images. Using race and gender information reduced the target gallery size. In [3], Forensic sketches to digital face images matching using Enhanced Uniform Circular local binary pattern (EUCLBP) matching algorithm. Memetic algorithm is used to optimize such large search spaces. The main objective of the project is to improve the recognition rate and identification accuracy for the given forensic sketch image.

Discrete Wavelet Transform (DWT) fusion based pre-processing technique is used to enhance the quality of sketch as well as photo and improve the identification performance. It's an automatic sketch to digital face image matching system. It can deal with viewed sketches, semi forensic sketches and forensic sketch. Viewed sketch and semi forensic sketch has no importance in the case of law enforcement agency.

In [11], automatic recognition of suspects from forensic sketch is performed here. In this approach self-similarity features are extracting from sketch and photo. Self-similarity features are obtained by correlating a small image patch within its larger neighbourhood and therefore, remain relatively invariant to the inter-modality variation. In pre-processing step, Difference-of-Gaussian (DoG) filter is used for reducing the low frequency information and retaining the high frequency information. FSS descriptor is computed by 2 steps. The first step is to compute a local self-similarity surface at a point. The second step is to convert the similarity surface into a polar histogram. FSS Descriptor Matching is done by using nearest neighbour classification. The minimum distance between probe-gallery pair is obtained by using the Euclidean distance function. This FSS descriptor is uses the CUHK Face Sketch database using sketch-photo pairs of 311 subjects. In [5], Multi-scale Circular WLD (MCWLD) is used. It is one of the most advanced types of image descriptors. This paper presents an automated algorithm to extract discriminating information from local regions of sketch and face photos. WLD is optimized for matching sketches with digital face images by computing the multi-scale descriptor in a circular manner.

Memetic optimization algorithm is used to assign optimal weights to every local facial region to boost the identification performance. This algorithm extracts the discriminating information from local regions of both digital face images and sketches. A pre-processing technique is presented for enhancing the quality of forensic sketch-digital image pairs. MCWLD has two components: 1) differential excitation and 2) gradient orientation. It uses viewed and forensic sketches. In [4], automatic matching of composite sketch to mug shot photograph is addressed. This paper proposes a component based representation to measure the similarity between composite sketch and mug shot. It consists of following steps. FSirst of all it automatically detects facial landmarks in composite sketch and mug shot using ASM (Active shape model).

Features are then extracting for each facial components using multi scale local binary pattern (MLBP) and per component similarity is calculated. 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 mug shot images using gender information. It matches 123 composite sketches against two galleries with 10,123 and 1,316 mug shots. This paper [2] describes an approach for matching facial composite sketches to police mug shot. This method is based on Geometric Features.

IV. THE FACESKETCHID SYSTEM

In The FaceSketchID System [6], Scott J. Klum, Han, Brendan F. Klare and Anil K. Jain are used two main algorithms for matching facial composites to mug shot database such as holistic algorithm and component based algorithm. Match scores of 2 algorithms (holistic and component-based) are fused together to boost matching performance. The main algorithm items used in this system are LDA and PCA, MLBP, SHIFT etc. The FaceSketchID System was developed to address the lack of a fully automatic means to match facial composites to mug shots

The FaceSketchID System supports a drag-and-drop enrolment interface with options for manually modifying detected eye locations, viewing both probe and target images after algorithm processing, viewing similarity heat maps of mug shot matches, and searching for known individuals by name within the mug shot matches. The FaceSketchID System also supports filtering the mug shot gallery via demographic information in the form of age range, race, and gender.

C. Holistic Algorithm

The holistic algorithm starts with the detection of the eyes of the sketch that we are giving as input. After detecting eye locations, the facial composite is normalized to a fixed height and width and transformed such that right and left eyes are at
the same position for every composite. The centre-surround divisive normalization (CSDN) filter is then applied to the composite to compensate for the differences related to the change in modality between composite and mug shot. CSDN filter results in the best matching performance for composites, and the resulting reduction in complexity increases the algorithm speed. Subsequently, SIFT and multi-scale local binary pattern (MLBP) features are extracted in parallel from a dense grid and uniform patches across the face, respectively. For both SIFT and MLBP features, optimal subspaces are learned for each patch using linear discriminant analysis (LDA). After learning an optimal subspace for each patch and projecting the patch-wise features into their respective subspaces, the projected features are concatenated to form a single feature vector.

PCA is applied to the feature vector to reduce template size, and the resulting feature vector is normalized using the L^2 norm. To measure the similarity between feature vectors, the holistic algorithm uses the L^2 similarity measure. After z-score normalization, scores from the SIFT and MLBP representations are fused via a sum-of-score fusion rule with equal weight applied to both representations. A diagram of the holistic algorithm pipeline is shown in Figure 5.

D. Component-Based Algorithm

In the component-based algorithm, facial components are automatically localized by detecting landmarks with an active shape model (ASM) via the STASM library. Procrustes alignment of landmarks improved the matching accuracy, especially when matching off-pose facial image. After component alignment and texture mapping, MLBP

descriptors are used to capture the texture and structure of patches in each facial component.

A PCA step is used to reduce the noise present in the patch-wise MBLP representation for the given facial component. Similar to holistic algorithm, the component-based method uses LDA to learn the optimal subspace and improve recognition accuracy. Using L^2 norm the feature vector comparison is performed. Scores are normalized prior to fusion using z-score normalization. Figure 6 describes component-based algorithm.Simple sum-fusion rule is used when fusing the match scores from both algorithms to boost the matching performance.

V. Enhancement to the System

FaceSketchID system automatically matches facial composites to mug shots. Hand-drawn composites, software-generated composites and surveillance composites are considered here. The main algorithm items used in this system are MLBP, SHIFT. Matching accuracy mainly depends upon features extracted. SIFT and MLBP are used feature descriptors. SIFT is still quite slow (SURF provides similar performance while running fast) and SIFT doesn't work well with lighting changes and blur.

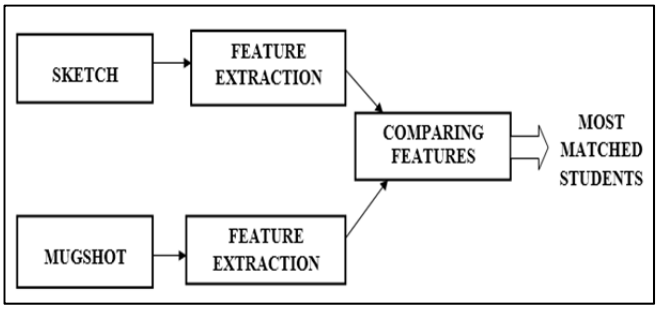

Figure 7. Basic Outline of Algorithm

So by enhancing these algorithms can improve performance of matching sketch with mug shot. By making some modifications to this FaceSketchID system, we can achieve this. Figure 7 shows outline for algorithm working. Modified method uses 2 algorithms.1) Enhanced holistic algorithm 2) Enhanced component-based algorithm.

Match scores of 2 algorithms are combined to boost performance. The core sub algorithm used for the existing system was LDA (Linear Discriminant Analysis) and PCA (Principal Component Analysis), which is used for the matching of the composites of face and all. Here my proposed system is to modify the exiting algorithm with some components. Matching accuracy mainly depends upon features extracted.

Since SIFT feature descriptor is still quite slow and it doesn't work well with lighting changes and blur. SURF provides similar performance while running fast and SIFT. So replacing SIFT with SURF will improve speed of system. Using Haralick texture feature instead of MLBP feature will improve performance. Figure 8 shows a input sketch given to the system. After performing enhanced holistic and enhanced component based algorithm matched result is shown in figure 9. Figure 9 shows some matched result which is displayed based on most matched order.

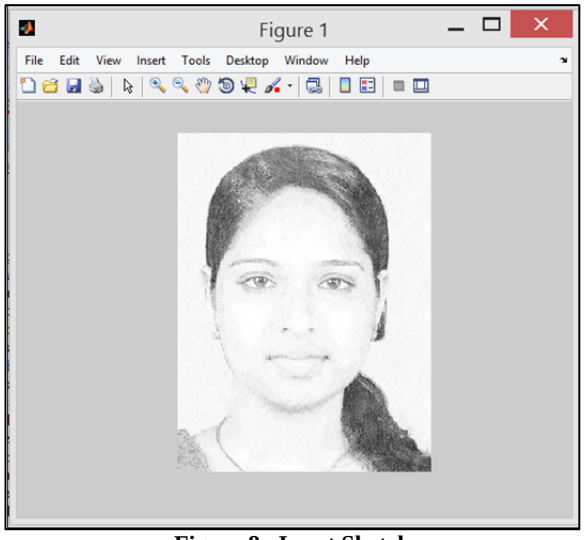

Figure 8. Input Sketch

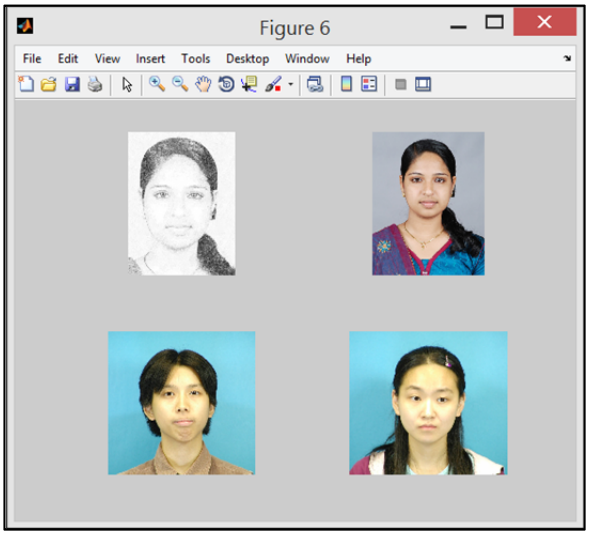

Figure 9. Output showing most matched results.

VI. Conclusion

Sketch to mug shot matching is very pertinent to law enforcement agencies. Sketches are used in law enforcement agency for the identification of suspects involved in criminal activities. Forensic sketches, composite sketches and surveillance composites are more valuable in the case of law enforcement agency for identification of criminals.

There are many methods used for this purpose. Most of them deals with one type of sketches and not automatic. From these FaceSketchID system is more efficient. Because it can deal with every type of sketch and its fully automatic. Better performance than other methods in terms of profit parameters. So making enhancement to this system will improve matching accuracy.

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AUTHORS

Chippy Thomas received the B.Tech degree in computer science from Calicut University, Kerala, India, in 2014 and currently doing M.Tech in Computer Science and Engineering from Met's School of Engineering, Calicut University, Kerala, India.

Dr.D.Loganathan is a Professor and Head of Computer Science and Engineering department in MET'S School of Engineering, Mala, Trissur, Kerala. After his B.E., and M.E degree, he accomplished a doctoral degree from Anna University, Chennai, India. He has more than 19 years of teaching experience and having 7 years of research experience in engineering field. His research interest includes Wireless Communication, Wireless Ad hoc Networks and Image Processing. He has published several research papers in various international journals.