A Survey of Face Recognition from Sketches

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Abstract- Face recognition has become one of the important application in today's life. It is basically used for digital entertainment, security and law enforcement. Face recognition can be for entire or partial face, the complete face considered for the entire face detection and specific features considered for the partial face detection. In most of the criminal cases, the investigation depends upon the sketches drawn according to the description provided by the eye-witnesses. The automatic retrieval of the photos matching to that description from the police mug-shot database can help reduce the number of suspects potentially. Basically, this process relies upon the recollection of the face by an eye-witness and accuracy of the sketch artist in catching those details. So, a stronger algorithm for even partial face recognition can be useful.

Keywords – Face Recognition; sketches; mug-shot; face-sketch recognition; law enforcement.

I. INTRODUCTION

A facial recognition system is basically a computer application capable of identifying or verifying a person from a digital image or a video frame from a video source. It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems. Face recognition has been proved as one of the most successful applications of image analysis and understanding.[1]

A. Law Enforcement

Many crimes occur where none of the information is present, but instead an eyewitness account of the crime is available. In such cases, a forensic artist is often made to work with the eye witness to draw a sketch of the culprit as described. Once this forensic sketch is ready, it is disseminated to law enforcement officers and media outlets hoping that someone might be knowing the suspect.[15]

This current process is much time consuming. Instead, if there is an automated process to fetch the potential suspects from the police mug shot, it would reduce this time to a great extent thereby making the task of finding out the suspects easier.

II. BACKGROUND

A. Uses of Face Recognition in Various Fields

1) User identification for access control
2) Border control
3) Computer and mobile devices
4) Information security
5) For criminal search

B. Types of Sketches[16]

Facial sketches can be classified into three types as described below:

1) Viewed Sketches:

- These type of sketches are drawn by hand while viewing the photograph.
- They are not relevant to forensic as they are not based upon the description.
- Hence, such sketched cannot be used in law enforcement scenarios.

2) Forensic Sketches:

- These are facial sketches drawn by forensic artists based on the description provided by an eye-witness.

- Forensic sketches are being used in criminal investigations since the 19th century.[17]

3) Composite Sketches:

- Composite sketches are facial sketches created using software kits allowing an operator to select different facial components.
- These type of sketches have been proved to be a popular and more affordable alternative to forensic sketches.
- Almost 80% of law enforcement agencies reported of using some kind of software to create facial sketches.[17]

C. Difficulties in face sketch recognition

Basically photographs and sketches belong to two different modalities. So, matching a photograph with a sketch or vice versa is a difficult and complicated job. The major difficulties that arise during matching face sketches with photos are:

- Due to the great difference between sketches and photos and the unknown psychological mechanism of sketch generation, face sketch recognition is much harder than normal face recognition based on photo images.
- The patches drawn by pencil on paper have different texture compared to human skin captured on a photo. In order to convey the 3D shading information, some shadow texture is often added to sketches by artists.
- For shape, a sketch exaggerates some distinctive facial features just like a caricature, and thus involves shape deformation.

D. Solutions to the difficulties

Solutions to the above mentioned problems can be as follows:

1) Conversion of photograph into sketch or vice versa:

- To first transform face photos into sketch drawings and then match a query sketch with the synthesized sketches in the same modality.
- A very common process is to convert the available photographs into sketches. Once the database of sketches is available, it becomes easier to match the sketch with the database.
- The second approach is to first transform a query sketch into a photo image and then match the synthesized photo with real photos in the gallery.

2) Direct feature extraction from the sketch:

- A problem with the above method is that it is time consuming.
- Also, the sketch that has to be matched is not a perfect one as it depends upon recollection of eye-witness. So even if the database is available for sketches, it is difficult to get a perfect match from it.
- Instead, if the features can be identified in the given sketch itself and compared

III. Importance of Automatic Face Recognition

For criminal search, the necessity of face recognition is increasing rapidly in order to identify the criminal from the description provided by the eye-witness. Usually, a sketch artist prepares a sketch from the description. Previously, the identification was being done manually by a human observer. It is a time consuming process and its accuracy is affected by the level of human expertise. That is why automatic face recognition from sketches is important.

Photographs and sketches have some basic differences such as:

1) Shadow
2) Texture
3) Shape

So, it becomes very difficult to match the heterogeneous images with high accuracy. To overcome these difficulties, numerous methods are studied.

IV. Embedded Hidden Markov Model [2]

A. E-HMM Representation for face image

- The trained E-HMM of the input image is obtained using the Baum-Welch algorithm.

- Then, the image sequence is decoded with the embedded Viterbi algorithm so that the optimal state sequence and mixture indices are determined.
- Since each state has a Gaussian probability density function (PDF), the observation of the most likely output image is equal to the mean vector in the model at the optimal state and index.

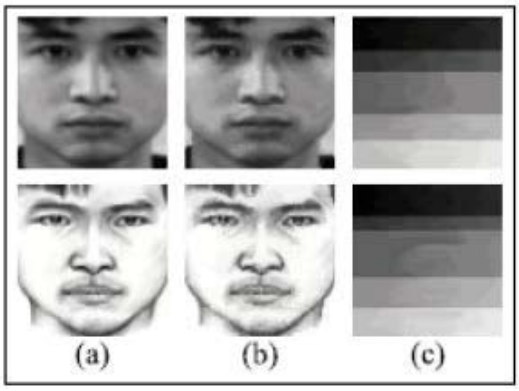

Figure 1 The reconstructed images and the state sequences based on E-HMM: (a) The original images; (b) The reconstructed images; (c) The state equences.

B. Sketch synthesis based on E-HMM

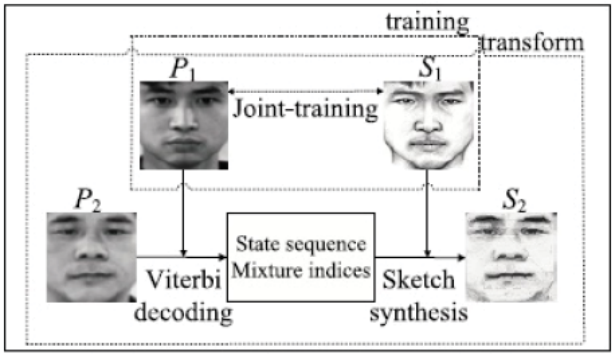

Figure 2 The framework of sketch synthesis algorithm based on E-HMM.

The sketch synthesis algorithm proposed is illustrated by figure 2.

1) Algorithm:

1) Obtain the E-HMM of the photo P1 and the E-HMM of the sketch S1 by conducting joint-training for the given photo-sketch pair (P1, S1).
2) Decode the input photo using the model P1.
3) Synthesize the pseudo-sketch S2 using the decoded sequence and the E-HMM S1.

Viterbi decoding gives the deformation from P1 to P2, while partial deformations from P1 to S1 are learnt by joint training.

2) Applications:

- Counter-strike
- Safety guard
- Image or video retrieval based

3) Limitations: The disadvantage of the E-HMM is that it is hard to learn more complex nonlinear relationship.

V. GEOMETRIC FEATURE BASED FACE SKETCH RECOGNITION [4], [5], [6]

In this approach, the extraction of geometrical features on face is the most important part. This includes the lengths, widths, their ratios of different facial parts such as mouth, eyes, nose, lips, etc. The commonly considered facial features can be listed as follows:

1) Face Cutting: Area of face.
2) Left Eye: Length, Width.
3) Right Eye: Length, Width.
4) Left Eyebrow: Length.
5) Right Eyebrow: Length.
6) Nose: Length.
7) Lip: Length, Width, Area.
8) Distance between upper-lip and nostril

The face region is first extracted and then these features are extracted one by one from the extracted face. At last, K-NN classifier has been employed to recognize probe face sketch through face photos database. The method can be used with or without converting the photo into a sketch. Conversion gives better results.

C. *Success of the approach*

The success of this approach with respect to eigen faces and sketch transform method can be seen from following table. [4]

The table shows it very clearly that results for geometric feature extraction method are better.

RANK	1	2	3	4	5
EIGEN FACES	26	33.8	47.1	52.4	55
SKETCH TRANSFORM	71	78	81	84	88
GEOMETRIC FEATURE	80	82.1	84	90.1	92.4

TABLE 1 SUCCESS OF GEOMETRIC FEATURE EXTRACTION METHOD: MATCHING PERCENTAGE

D. *Limitations*

- This is different and difficult than face photo recognition because faces are much different from sketches in terms of color, texture, and projection details of 3D faces in 2D images.[4]
- Geometrical features change with the facial expression.[6]

VI. BYPASSING SYNTHESIS(POSE, LOW RESOLUTION AND SKETCHES)[7]

PLS i.e. Partial Least Squares method can be used effectively for feature selection in face recognition across different modalities. A generic intermediate subspace comparison framework for multi-modal recognition is formulated.

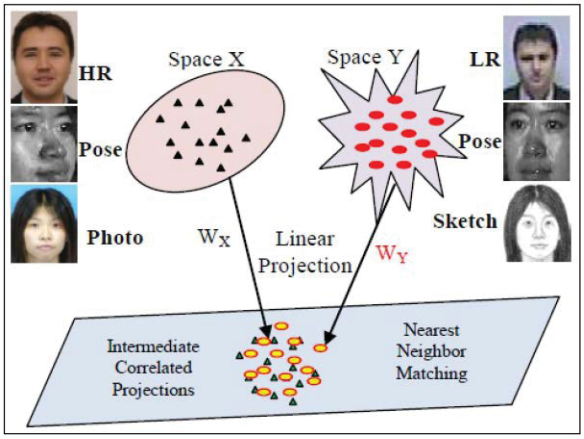

Figure 3 The basic over-view of the method, WX and WY are projection atrices learned using PLS on X and Y.

The approach basically argues for the applicability of linear projection to an intermediate subspace for multi-modal recognition, also pointing out the value of the Bilinear Model (BLM) for face recognition, which also achieves state-of-the art results on some problems.

A. *Partial Least Square*

- Partial Least Square analysis is a regression model that differs from Ordinary Least Square regression by first projecting the regressors i.e. inputs and responses i.e. outputs onto a low dimensional latent linear subspace.
- PLS chooses the linear projections such that the covariance between latent scores of inputs and outputs is maximized and then a linear mapping from the regressors latent score to responses latent score is established.
- PLS is applied by using images from one modality as regressors and those from different modality as responses.
- Thus a linear projection for each modality maps images into a common space and then they can be compared.

B. *Bilinear Model[8]*

Bilinear models offer a powerful framework for extracting the two-factor structure of a set of observations, and are familiar in computational vision from several well-known lines of research.

- The two factors are generically considered as style and content.
- In cross-modal face recognition, the two modes correspond to two styles, and subject identity corresponds to content.

The method is useful for face recognition against following odds:

- Pose
- Low Resolution images
- Sketch

Using this approach, comparable performance for sketch photo and cross resolution face recognition is achieved.

VII. COUPLED INFORMATION (THEORETIC ENCODING)[9]

The approach stressed upon reducing the modality gap at the time of feature extraction. To achieve that, coupled information theoretic projection (CITP) was used.

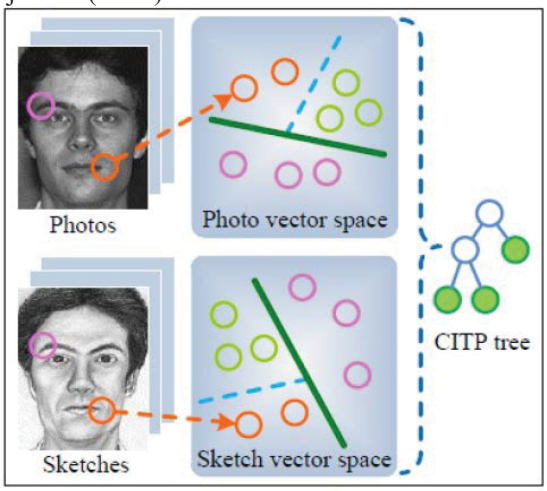

Figure 4 A CITP tree with three levels

- The local structures of photos and sketches are sampled and coupled encoded via the CITP tree.
- Each leaf node of the CITP tree corresponds to a cell in the photo vector space and in the sketch vector space.
- The sampled vectors in the same cell are assigned the same code, so that different local structures have different codes and the same structures in different modalities have the same code.

VIII. LOCAL RADON BINARY PATTERN[10]

A. *Local Radon Binary Pattern*

LRBP i.e. Locan Radon Binary Pattern is based upon the fact that the shape of a face photo and corresponding sketch remains the same even if the sketch is exaggerated by an artist and hence the shape of face can be exploited to compute features which are robust against modality differences between face photo and sketch.

1) Radon Transform: Radon transform computes projections of image intensity along tracing lines. Each line is characterized by its distance to the origin and rotation angle from reference axes.

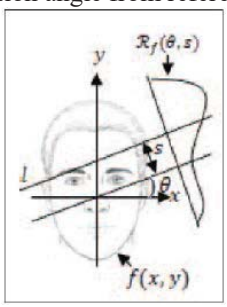

Fig. 5. Radon Transform

2) Local Binary Pattern: LBP or Local Binary Pattern was originally introduced as a gray-scale invariant descriptor for texture analysis and later, LBP has been applied for many computer vision applications due to its discriminative power and computational efficiency. Practically, it assigns a binary string to each pixel of an image by thresholding sampling pixels on a circle.

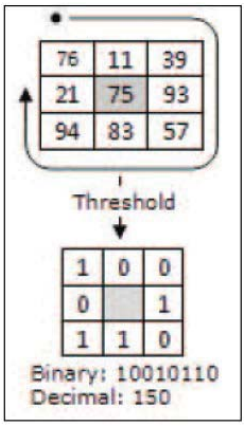

Fig. 6. LBP Operator

3) Local Radon Binary Pattern: In LRBP, LBP is applied on the transformed image in Radon space. By doing this LRBP encodes the shape of face which is invariant to different modalities. Then individual and concatenated histograms are plotted and analysed.

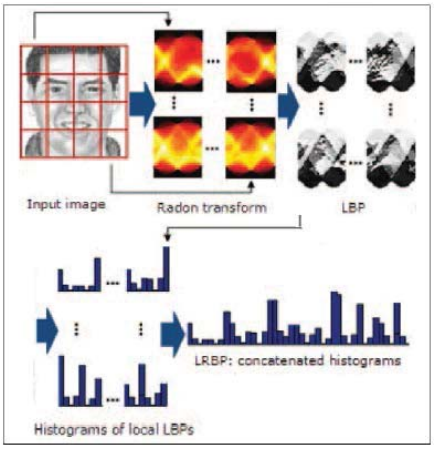

Fig. 7. Framework of LRBP at level 2

IX. Markov Random Fields[11]

The system uses a multiscale Markov Random Fields (MRF) model. It involves three parts basically.

- Given a face photo, synthesizing a sketch drawing
- Given a face sketch drawing, synthesizing a photo
- Searching for face photos in the database based on a query sketch drawn by an artist

The approach focuses on synthesizing local face structures at different scales using a Markov Random Fields model than focusing upon the global features which are difficult to extract.

It requires a training set containing photo-sketch pairs.

B. Assumptions

- Faces to be studied are in a frontal pose
- Faces to be studied are with normal lighting
- Faces to be studied are with neutral expression
- Faces to be studied are have no occlusions

The face region is divided into overlapping patches. During sketch synthesis, for a photo patch from the face to be synthesized, a similar photo patch from the training set is found and its corresponding sketch patch in the training set is used to estimate the sketch patch to be synthesized.

X. Modality Reduction By Transform and Feature Extraction Using PCA[12]

C. Eigen faces algorithm

- Face image can be reconstructed from eigenfaces in the PCA representation.
- Since eigenface is computed from the training set, the reconstructed face image can also be expressed as the linear combination of training samples.

D. Face sketch recognition

Face sketch recognition is based on the matching between the probing real sketch and the synthesized pseudo-sketch from photo. For that, PCA i.e. Principle Component Analysis and Baysian classifiers are used.

In place of Eigen transform as described in the above method, 2-D wavelet transform or 2-D Discrete Cosine transform can also be used in order to improve accuracy.[13],[14]

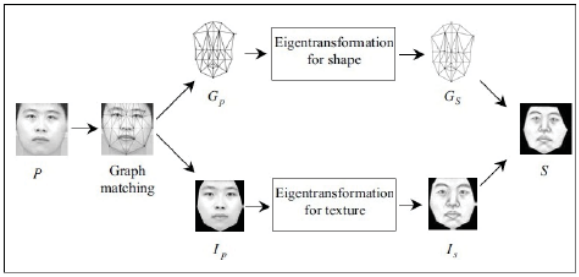

Fig. 8. Framework of the face sketch synthesis system

XI. Summary

The above mentioned face sketch recognition systems can be classified based upon the types of sketches. According to the types used, they can be summarized as follows:

A. Viewed Sketches

Publication	Approach	Limitations
Tang and Wang[6]	Photo-to-sketch conversion using eigen transform	Viewed sketches are not useful in law enforcement and forensics applications. Conversion methods often solve a more difficult problem than the recognition task.
Liu et al[18]	Photo-to-sketch conversion using locally linear embedding	
Gao et al[3]	Photo-to-sketch conversion using embedded hidden Markov model	
Wang and Tang[11]	Photo-to-sketch conversion using multiscale Markov random field model	
Lin and Tang[19]	Common discriminant feature extraction	
Zhang et al [20]	PCA based algorithm	

TABLE 2 SUMMARY OF FACE SKETCH RECOGNITION METHODS USING VIEWED SKETCHES

B. Forensic Sketches

Publication	Approach	Limitations
Uhl and Lobo [5]	Photometric standardization	Composite sketches, which are widely used in law enforcement, were not considered.
Klare and Jain [21]	SIFT and MBLP feature descriptors with local-feature based discriminant analysis	
Bhatt et al [22]	Mmulti-scale circular webers local descriptor	

TABLE 3 SUMMARY OF FACE SKETCH RECOGNITION METHODS USING FORENSIC SKETCHES

C. Composite Sketches

Publication	Approach	Limitations
Yuen and Man[23]	Point distribution model and geometrical relationship	Composite sketches were created while viewing the photograph. Forensic sketches were not considered.
Han et al [24]	Component based representation using MLBP descriptors	

TABLE 4 SUMMARY OF FACE SKETCH RECOGNITION METHODS USING COMPOSITE SKETCHES

D. Forensic and Composite Sketches both

Publication	Approach	Limitations
Klum, Han, Jain[17]	Both forensic and composite sketches are studied using two representations methods. Demographic information is used to improve the matching performance.	Complicated procedure

TABLE 5 SUMMARY OF FACE SKETCH RECOGNITION METHODS USING FORENSIC AND COMPOSITE SKETCHES BOTH

XII.CONCLUSION

1) Although a lot of research has been done and number of methods to achieve face recognition have been evolved, the results are largely affected by conditions imposed by many real time applications which can be listed as follows:
   - Outdoor environment
   - Illumination
   - Pose
   - Accuracy of sketch drawn

   That is how current systems are still far away from the capability of the human perception system. [1]
2) Within the types of sketches, forensic and composite sketches prove to be good as far as law enforcement is concerned.
3) Direct feature extraction from sketches proves to be better than conversion of photograph to sketch or vice-versa as it is consumes more time as well as memory.

REFERENCES

[1] W. ZHAO, R. CHELLAPPA, P. J. PHILLIPS, A. ROSENFELD, "Face Recognition: A Literature Survey", ACM Computing Surveys, Vol. 35, No. 4, December 2003, pp. 399458.

[2] Juanjuan Zhong, Xinbo Gao, Chunna Tian, "FACE SKETCH SYNTHESIS USING E-HMM AND SELECTIVE ENSEMBLE", 1424407281/07/2007 IEEE

[3] Xinbo Gao, Juanjuan Zhong, Jie Li Chunna Tian, "Face Sketch Synthesis Algorithm Based on E-HMM and Selective Ensemble", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, VOL. 18, NO. 4, APRIL 2008

[4] Sourav Pramanik, Debotosh Bhattacharjee, "GEOMETRIC FEATURE BASED FACE-SKETCH RECOGNITION", Proceedings of the International Conference on Pattern Recognition, Informatics and Medical Engineering , March 21-23, 2012

[5] Robert G. Uhl Jr., Niels da Vitoria Lobo, "A framework for recognizing a facial image from a police sketch", 1063-6919/96 1996 IEEE

[6] Xiaoou Tang, Xiaogang Wang, "Face Sketch Recognition", IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, VOL. 14, NO. 1, JANUARY 2004

[7] Abhishek Sharma, David W. Jacobs, "Bypassing Synthesis: PLS for Face Recognition with Pose, Low-Resolution and Sketch"

[8] W. T. Freeman, J. B. Tenenbaum, "Learning bilinear models for two factor problems in vision"

[9] Wei Zhang, Xiaogang Wang, Xiaoou Tang, "Coupled Information-Theoretic Encoding for Face Photo-Sketch Recognition"

[10] Hamed Kiani Galoogahi and Terence Sim, "FACE SKETCH RECOGNITION BY LOCAL RADON BINARY PATTERN: LRBP", 978-1-4673-2533-2/12/2012 IEEE

[11] Xiaogang Wang, Xiaoou Tang, "Face Photo-Sketch Synthesis and Recognition", IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 31, NO. 11, NOVEMBER 2009

[12] Xiaoou Tang, Xiaogang Wang, ”Face Sketch Synthesis and recognition”, Proceedings of the Ninth IEEE International Conference on Computer Vision (ICCV 2003) 2-Volume Set

[13] Sourav Pramanik, Dr. Debotosh Bhattacharjee, ”An Approach: Modality Reduction and Face-Sketch Recognition”

[14] Vineet Srivastava, ”Forensic Face Sketch Recognition Using Computer Vision”, International Journal on Recent and Innovation Trends in Computing and Communication ISSN 2321 8169 Volume: 1 Issue: 4

[15] Dipeeka S. Mukane, , S. M. Hundiwale, Pravin U. Dere, ”EMERGING FORENSIC FACE MATCHING TECHNOLOGY TO APPREHEND CRIMINALS: A SURVEY”, International Journal of Advances in Engineering and Technology, Mar. 2014. ISSN: 22311963

[16] Scott Klum, Hu Han, Anil K. Jain, Brendan Klare, ”Sketch Based Face Recognition: Forensic vs. Composite Sketches”.

[17] D. Mcquiston, L. Topp, and R. Malpass, Use of facial composite systems in US law enforcement agencies, Psychology, Crime and Law,vol. 12, no. 5, pp. 505517, 2006.

[18] Q. Liu, X. Tang, H. Jin, H. Lu, and S. Ma, A nonlinear approach for face sketch synthesis and recognition, Proc. IEEE Conf. Computer Vision and Pattern Recognition, pp. 10051010, June 2005.

[19] D. Lin and X. Tang, Inter-modality face recognition, Proc. ECCV, pp. 1326, 2006.

[20] Y. Zhang, C. McCullough, J. Sullins, and C. Ross, “Handdrawn face sketch recognition by humans and a pca-based algorithm for forensic applications,” IEEE Trans. SMC, Part A: Systems and Humans, vol. 40, pp. 475–485, May 2010.

[21] B. Klare, Z. Li, and A. Jain, “Matching forensic sketches to mug shot photos,” IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 33, pp. 639–646, March 2011.

[22] H. Bhatt, S. Bharadwaj, R. Singh, and M. Vatsa, “Memetically optimized mcwld for matching sketches with digital face images,” IEEE Trans. on Information Forensics and Security, vol. 7, pp. 1522–1535, October 2012.

[23] P. Yuen and C. Man, “Human face image searching system using sketches,” IEEE Trans. SMC, Part A: Systems and Humans, vol. 37, pp. 493–504, July 2007.

[24] H. Han, B. Klare, K. Bonnen, and A. Jain, “Matching composite sketches to face photos: A component based approach,” IEEE Trans. on Information Forensics and Security, vol. 8, pp. 191–204, January 2013.