Sketch-Face Recognition Using Hybrid of HOG and GLCM Feature Descriptors

A Dissertation submitted towards the partial fulfillment of
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Submitted by

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CERTIFICATE

This is to certify that the dissertation title "**Sketch-Face Recognition Using Hybrid of HOG and GLCM Descriptors**" submitted by **Mr. SANCHIT KUMAR Roll. No. 2K14/SPD/16**, in partial fulfilment for the award of degree of Master of Technology in "**Signal Processing and Digital Design(SPDD)",** run by Department of Electronics & Communication Engineering in Delhi Technological University during the year 2014-2016., is a bonafide record of student's own work carried out by him under my supervision and guidance in the academic session 2018-19. To the best of my belief and knowledge the matter embodied in dissertation has not been submitted for the award of any other degree or certificate in this or any other university or institute.

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DECLARATION

I hereby declare that all the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. This report is my own work to the best of my belief and knowledge. I have fully cited all material by others which I have used in my work. It is being submitted for the degree of Master of Technology in Signal Processing & Digital Design at the Delhi Technological University. To the best of my belief and knowledge it has not been submitted before for any degree or examination in any other university.

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ABSTRACT

Sketch-Photograph matching assumes an essential job in law enforcement to get offenders and a few years before sketch and photograph matching was done physically which was a tedious procedure. In past decade, different programmed sketch face matching procedures have been proposed to make the matching framework increasingly accurate and less tedious. Yet, issue with these frameworks are that in the event that they give great accuracy, at that point they exchange off it with high time utilization and computational expense and on the off chance that they attempt to lessen time utilization and computational cost, at that point they don't give great accuracy.

So, to handle these issues an automatic system for sketch-face matching has been proposed in this thesis which gives great accuracy with lesser time utilization and computational expense. In our project, preprocessing is finished by changing over both the sketches and photographs to gray images and afterward processed with median filter to expel noise from the images while safeguarding edges in the images. The primary advance in our project includes feature calculation which has been finished utilizing hybrid of two different types of descriptors i.e. Histogram of oriented gradients (HOG) and Gray level Co-occurrence matrix (GLCM). After calculating the feature vectors for images, they have been utilized for matching purpose using Euclidean distance. Since, simple Euclidean distance has been utilized, time and computational utilization is extremely low in this project and hybrid of 2 distinctive feature descriptors gives great outcomes.

Key words: Sketch-photo matching, HOG, GLCM and Euclidean distance.

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Chapter 1

Introduction to sketch and photo matching system

1.0 Overview

In today's world, progresses in biometric technology have given law enforcement authorities extra tools in the recognizable proof of criminals. In addition to the accidental proof, if an important fingerprint is found at the scene of crime or a surveillance camera catches a picture of the face of a suspect, at that point these pieces of information are used in deciding the criminal utilizing biometric recognizable techniques. However, in many cases the information like fingerprints is not available at the crime scene. Likewise, the absence of technology to viably catch the biometric information like fingerprints inside a limited time and capacity to focus the scene of crime, is a standard issue in remote regions. In spite of these repercussions, in many cases, an eyewitness of the incident is accessible who had seen the criminal. The Police department utilizes the art of a forensic artist to work with the observer so as to draw a sketch that matches the facial appearance of the suspect. When the sketch is prepared, it is sent to the law enforcement officers and news sources with the desire for getting the suspect. Then the sketch is matched with the photos available with the department to recognize the suspect and photo is available only if that person is convicted at least once. In earlier times, this recognition was done manually which is a time consuming process, then came into existence the automatic recognition techniques. Many automatic recognition techniques have been introduced so far and it has been tried to improve these techniques through the work mentioned in this thesis. In this thesis, an effective automatic recognition systems has been introduced using hybrid of two descriptors i.e. histogram of oriented gradient (HOG) descriptors and gray level co-occurrence matrix (GLCM) descriptors.

1.1 Sketches

A sketch is an illustration that is done rapidly without a great deal of information. Artists frequently use sketches as a preparation for more detailed painting or drawing. There are two types of sketches in our scenario i.e. viewed sketch (fig. 1.1) and forensic sketch (fig. 1.2):

1.1.1 **Viewed Sketches**: These sketches are drawn by the artist by keeping the subject or photograph of the subject directly in front of him.

1.1.2 **Forensic Sketches**: These sketches are drawn by the artist using the information given to him by the eyewitness of the crime scene who has seen the suspect.

It can be noticed from the above description that viewed sketches contain more accurate information of the suspect than the forensic sketches. So, viewed sketches give more accurate matching results in the automatic recognition system. Therefore, to get accurate results viewed sketches have been used in the proposed work.

Fig 1.1: Viewed Sketch and its corresponding photograph

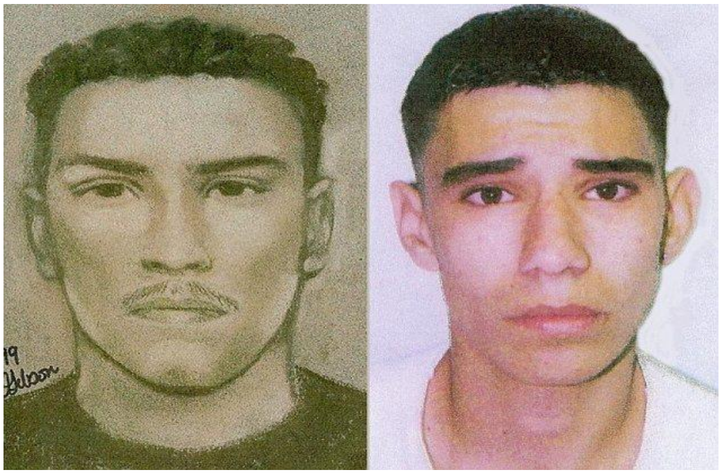


Fig 1.2: Forensic Sketch and its corresponding photograph

1.2 Sketch Recognition

Police sketching techniques are as yet an everyday practice of law enforcement investigation and regularly used to distinguish suspects from an eyewitness memory. These traditional techniques of recognizing are for the most part hand-worked, meticulous and may not lead to capture the correct guilty party. In this manner, an automatic face sketch recognition framework that decides productively the culprit appearance from an enormous gallery of face pictures is required. Such technology design is testing since faces and sketches are created from particular sources and have distinctive holes to overcome in low and high states. In the last decade, extraordinary efforts have been committed to the investigation of the computerization of face sketch acknowledgment and to add a new benchmark in the automatic face sketch recognition system, a new technique has been introduced to improve the framework of the recognition system.

1.3 Motivation

The fundamental motivation driving the endeavor of this project is that there are some issues in scientific sketch recognition contrasted with ordinary face recognition (in which both test and gallery pictures are photos). The texture of sketches, regardless of whether they might be viewed or forensic are very not quite the same as that of the gallery of photos that is being matched against. Previously work on sketch face recognition has been done mostly on viewed sketches but they give results with not greater accuracy as desired by the investigation agency (PCA/LDA+ Geometric information (wavelet method) [12], PCA (Eigen face features) with 94 % accuracy [12] 86% accuracy, PCA (DCT normalization features)[12] with 86% accuracy, Canonical correlation analysis (CCA) [18] with 94.6% accuracy and Partial least squares (PLS) [19] with 93.6% accuracy). So, in this thesis a more accurate and lesser time consuming systems has been designed.

1.4 Thesis Organization

This thesis is organized so that it gives a ceaseless and smooth stream of information to the reader, with respect to the advancement of automatic sketch face recognition system. The 5 chapters in this thesis are:

(a) Introduction
(b) Literature Review
(c) Research methodology and Proposed method
(d) Result and Discussion
(e) Conclusion

Chapter 2

Literature Review

2.0 Overview

This chapter describes the previous researches that have been done in this field by various researchers. Research in face sketch recognition began just a decade ago. This is on the grounds that the accuracy of sketch recognition is low, contrasted with customary face recognition. This is inturn because of a vast texture difference, between a sketch and a photograph. Since researchers struggled to get great outcomes with photograph to photograph recognition till the beginning of past decade, sketch recognition isn't embraced as a significant issue till at that point. Be that as it may, from that point onward, the research begun to spread like a backwoods discharge, where the academicians everywhere throughout the world, began burrowing the issue. The literature begins by reviewing some of the previous studies of automatic face sketch recognition systems. It also highlights the limitation of existing face sketch recognition systems.

2.1 Previous work

Work on automatic face sketch recognition systems started with the work of **Uhl and lobo** [1] who proposed the first automatic retrieval of photos using a query sketch based on face recognition algorithm based on **Principle Component Analysis (PCA)**.

After that the most work in this field was done by **Tang and Wang** [2] in which an automatic method for recognizing photos from a database using a sketch has been introduced in which a sketch is not matched with a photo directly as there is a great difference between a sketch and real photo in terms of shape and texture. So the database is first converted from the photos to sketches using Eigenface method which itself uses **Karhunen-Loeve Transform**. It also creates feature vector for the sketches in the database and the testing image. Then, the feature vectors of sketch and face are matched using **Euclidean Distance** and [3] an automatic photo sketch recognition method is introduced which has main components: (1) Photo/Sketch synthesis: In this step, either photo is transformed into sketch or sketch is transformed into photo using patch making process which uses **multiscale Markov Random Fields (MRF)** model to synthesis the patches matched. Then these matched patches are stitched to form a complete sketch/photo. Photo Recognition: Various classification methods are used for this step i.e. PC**A, Bayesianface (Bayes), Fisherface, null-space LDA, dual space LDA** and **Random Sampling LDA (RS-LDA)** for photo/sketch recognition. RS-LDA gives the highest accuracy amongst all. Limitation in the mentioned methods is that the system is time consuming and has high computational cost.

Han, Klare and Jain et al. [4] gave an automatic face- sketch recognition system using a **component based representation (CBR)**. **Klum, Han and Jain** et al. [5] gave a system in which the forensic sketches (made by sketch artist) and composite sketches (made using **FACES** software) both are used for facial recognition with original photos taken using two methods: (a) Holistic method (b) Component method. These two methods are compared with each other in terms of accuracy and also they both are also compared with a commercial face matching system **FaceVACS**. In holistic method, similarities between local features computed on uniform patches across the entire face image. The individual patch scores are combined to calculate an overall sketch to original photo match score. It uses **Random Sampling Linear discriminate analysis (RS-LDA)** to improve accuracy. In component method, similarity between individual facial components is used to compute an overall sketch to original photo match score. It uses **LDA** to improve accuracy. Problem with the usage of composite sketches is that sketches design depends totally on the person who is using the software to design them.

Liu and Bae [6] an automatic system is introduced for face-sketch recognition in which photos from two different modalities (i.e. Photos and Sketches) are matched directly using **Joint dictionary learning**. Firstly, the dictionaries from both the photos and sketches are jointly trained and then the coefficients of the tested data are calculated separately and compared using Cosine Distance. The proposed method is compared with the previously proposed methods like Canonical Correlation analysis (CCA), Partial Least Squares (PLS) and Coupled Dictionary Learning (CDL). It shows higher accuracy than CCA and PLS and accuracy comparable to CDL but the computational complexity is lower than CDL.

Roy and Bhattacharjee [7] an automatic face sketch photo matching system is introduced using the **Local Gradient Fuzzy Pattern (LGFP)** and Also Multiscale LGFP method was also tested in this paper and the two proposed methods i.e. single scaled LGFP and Multi scaled LGFP are compared with many previously introduced methods and it gives the highest accuracy of matching at Rank-1 itself. Method was time consuming and was having high computational cost.

Zhang and Gao [8] a robust generalized photo to sketch synthesizing method has been given based on sparse representation based greedy search (SR-GS). **Wang and Gao** [9] an automatic photo to sketch synthesizing method has been given based on **Anchored Neighborhood Index (ANI)**.

Galea and Farrugia [10] gave an automatic intermodility (i.e. photos of two different modularities like original photo and sketch) face recognition system based on **Deep Learning Based Architecture**. The proposed method is compared with many previously proposed methods like LGMS, D-RS+CBR, D-RS, PCA, HAOG etc and proposed method gives highest recognition rates amongst all. The computational complexity and time consumption increase due to more number of images per subject.

Setumin and Suandi [11] gave an automatic face sketch to photo matching method using **Difference of Gaussian Oriented Gradient Histogram (DoGOGH)** for Face Sketch to Photo Matching. The effectiveness of DoGOGH was evaluated and compared with several popular local descriptors (i.e., MLBP, SIFT, SURF, and HOG).

Chugh, Singh, Nagpal and Vatsa et al. [12] gave an automatic composite face sketch and photo matching method using **Transfer Learning based Evolutionary Algorithm**. The features are extracted using two feature descriptors methods: one is **Histogram of Oriented Gradient (HOG)** and other is proposed in this paper **Histogram of Image Moments (HIM)** descriptor for both the source and target domain. Then these feature vectors are given to the target domain and then features of both the domain are matched again using genetic learning and a match is decided at last. This process of transferring feature vectors from source domain to target domain is called Transfer Learning.

Patil and Shubhangi [13] gave an automatic forensic sketch to photo matching system using **Geometrical Face Model**. Face region is identified using AdaBoost algorithm and then facial main components like eyes, nose, mouth etc. are marked using geometrical structure of face. Then from each facial component a texture feature is extracted using Weber Local Descriptor (WLD). Then Artificial Neural Network (ANN) is used for classification.

Li and Yang [14] gave an automatic face sketches recognition system based on **generating photorealistic faces guided by Descriptive Attributes**. Given a minimal sketch along with the guidance of the descriptive attributes (i.e. verbal information of features given by witness), the photorealistic face is generated by the generation algorithm i.e. **multi-modal conditional generative adversarial network (MMC-GAN)**. Then the matching process can be conducted effectively based on the synthetic faces using then the matching process with the off-the-shelf recognition methods can be conducted effectively based on the synthetic faces by calculating Cosine distance of the representation for face feature matching to determine whether the two faces are similar or not.

Rajput and Prashantha [15] gave an automated face photo-sketch using HOG descriptors. Feature descriptors are extracted using **Histogram of Oriented Gradients (HoGs)**. Then photo and sketches are matched using **K-Nearest Neighbours (K-NN)** algorithm.

Zhang and Wang [16] gave an automatic and effective photo to sketch synthesizing method has been proposed based on **Dual-transfer** i.e. inter domain transfer and intra domain transfer. In inter domain, the knowledge of common information between the test and training photos has been used to induce a regressor of the former with respect to the latter. Under the similarity assumption on photo and sketch manifolds, this regressor can be transferred from the photo domain to the sketch domain. Almost all existing methods can be regarded as instantiations of inter-domain transfer, and, in the current work, a low-rank approximation-based instantiation has been developed that has much greater efficiency than previous ones. Our instantiation induces a linear formulation of inter domain transfer that is sufficient to synthesize common facial structures. In intra domain, we also propose a **generative adversarial network (GAN)** based modeling approach that is better suited to describing the complex relationship between two modalities. The proposed method has been compared with many existing methods like the MRF-based method, the MWF-based method, the SNS-SVR-based method, the TFSPS based method, the SSD-based method, the SST-based method, the FCN-based method, the GAN-based method and the DR-GAN-based method and proposed method is giving better result than all. This method is very complex and has high computational cost.

2.2 Summary

It can be seen above that two main problems with the above method are: (1) most of them are time consuming and have high computational complexity. (2) Some of them are not giving satisfying results in Rank-1 matching (i.e. correct matching of sketch with the photo that comes at the first attempt). So, in this thesis, it has been tried to overcome both the mentioned limitations to reduce computational time and complexity and also proposed method is giving better result in Rank-1 matching of sketches with the face photos.

Chapter 3

Proposed Method

3.0 Overview

This chapter provides step by step detailed approach of the proposed method for sketch to face matching system. The steps involved in the methods are: (1) Preprocessing of both sketches and photos. (2) Feature extraction of both the images using hybrid of HOG descriptors [16] and GLCM descriptors [17]. (3) Matching of sketch to photo using Euclidean distance. The flowchart of the proposed method has been given in fig 3.1.

3.1 System Requirements

This method has been implemented using MATLAB (Math Works Inc.) software tool (version 2017a), the numerical computing environment and programming language software for modeling complex algorithms. MATLAB is a problem-oriented language that allows performing computationally complex tasks quicker than the other programming language like C and C++. This software is the most commonly used development language.

3.2 Proposed Approach

3.2.1 Preprocessing of images

Preprocessing is one of the pivotal advances in image processing. It not just modifies the pictures into the alluring areas yet additionally expels pointless data like noise from the pictures to give better outcomes. Preprocessing in this project comprises of two procedures:

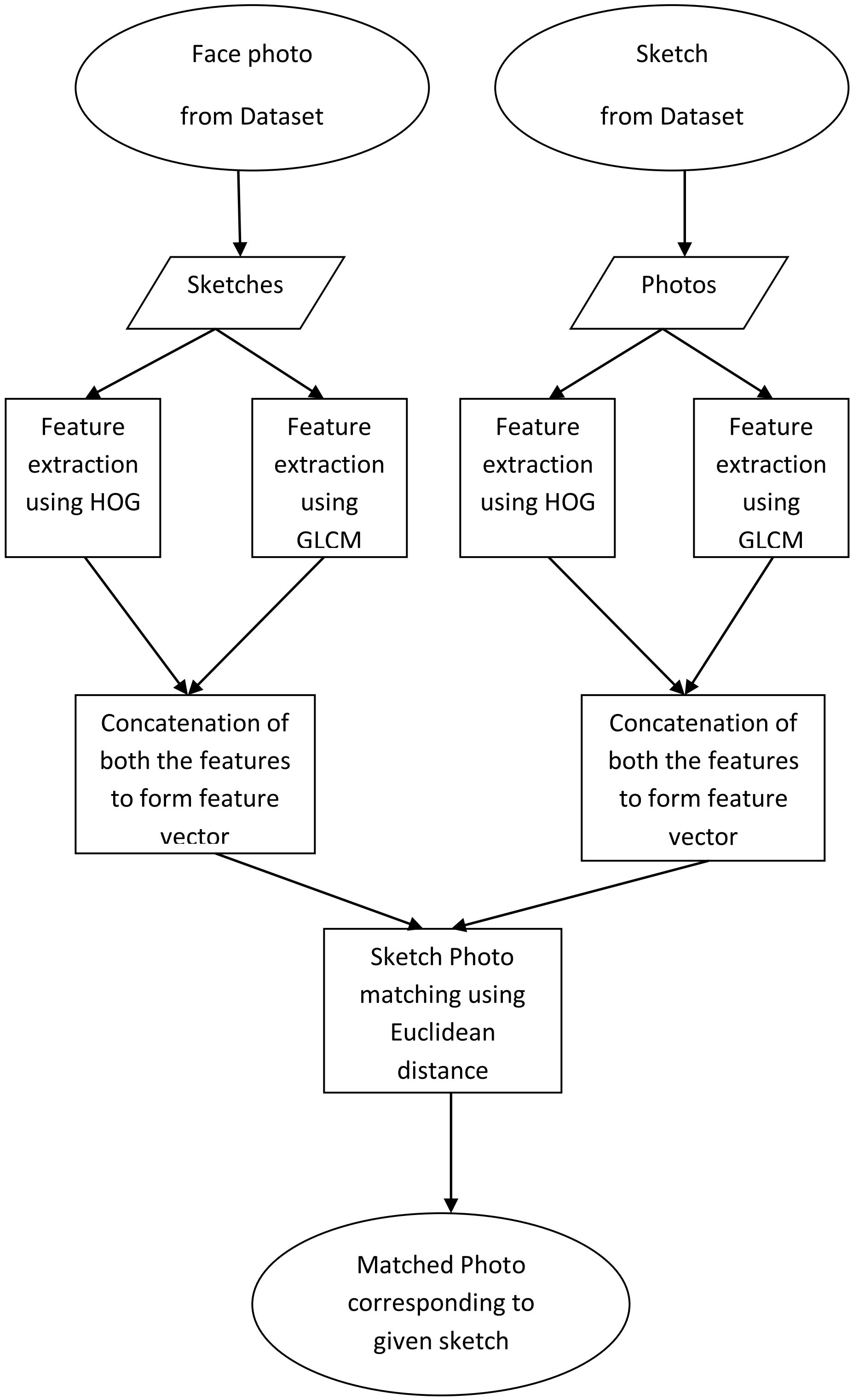


Fig 3.1 Flowchart of the proposed method

(a) Conversion of images from RGB (coloured) to gray (Black and White)

The dataset available with us consists of photos and sketches and both the images have more than 2 gray levels i.e. white and black. So, both photos and sketches are converted to gray images to make their gray levels into the same domain.

(b) Removal of noise from images using Median filter

Median filtering is a nonlinear method used to remove noise from images. It is widely used as it is very effective at removing noise while preserving edges. So, after transformation to gray images both sketch and photograph are processed with 2-D median filter which expels noise from the images while protecting their edges. It helps in giving great outcomes as the edges are saved and in this project edges are extremely useful in matching sketch and photographs.

3.2.2 Feature extraction

Feature extraction is the way toward characterizing a set of feature, or picture qualities, which will most productively or meaningfully represent the data that is essential for investigation and classification. Features in this project are calculated using two different techniques i.e. HOG descriptors and GLCM descriptors. Then features from both the techniques are concatenated to form a feature vector which will be used for matching of sketch to photo. Details of feature extraction are given below:

(a) Feature extraction using Histogram of Oriented Gradients (HOG).

The calculation of HOG features is done in 3 stages i.e. (1) Gradient Calculation (2) Histogram Generation (3) Block Normalization as depicted in block diagram given in fig. 3.2.

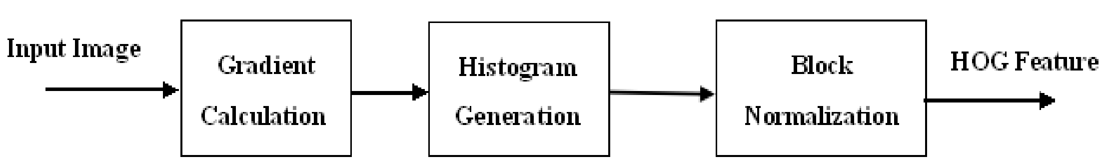


Fig 3.2 HOG features generation block diagram

These features will be calculated for every image and hence feature vector for that image will be formed for matching purpose. The details of each process of the above block diagram are given below:

(1) Gradient Calculation

Figure 3.3 demonstrates an idea of Cells and blocks utilized for HOG feature extraction. A Cell measure is 8x8 pixels. A block is arranged by gathering the 2x2 Cells.

The first step to extract HOG features is to calculate the difference values for x and y directions and are computed by using following equations:

$$f_x(x,y) = f(x+1,y) - f(x-1,y)$$
$$f_y(x,y) = f(x,y+1) - f(x,y-1) \quad (1)$$

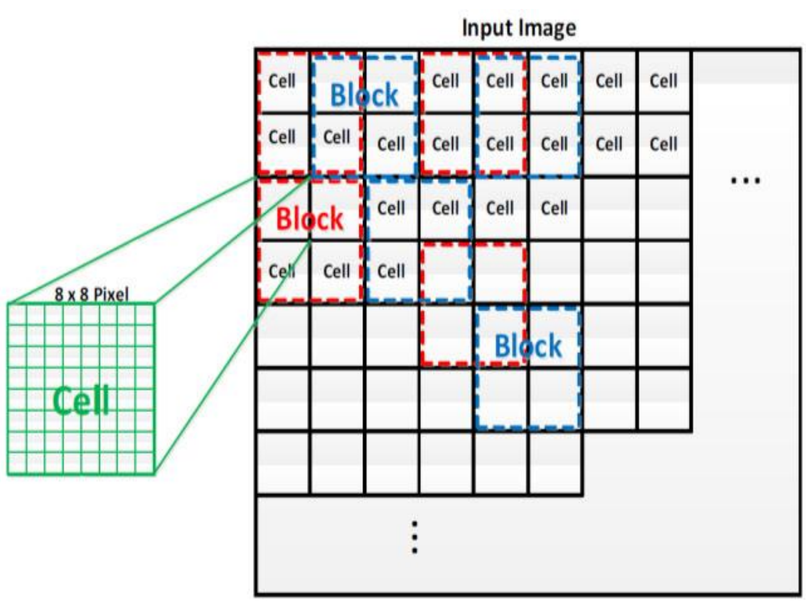


Fig 3.3 Cell and Block used for HOG. Each Cell is 8x8 pixels, Block is 2x2 Cells

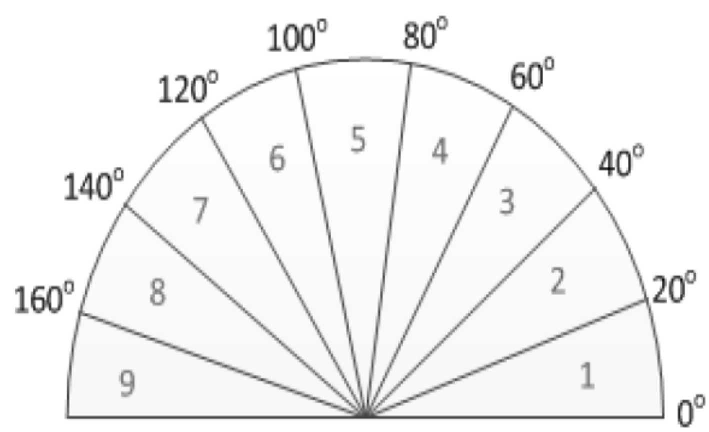
Where $f(x, y)$ is the pixel intensity value of the image for the pixel (x, y). Then the magnitude Arg and direction θ are calculated using equations (2) and (3) respectively.

$$Arg(x, y) = \sqrt{f_x(x, y)^2 + f_y(x, y)^2} \quad (2)$$

$$\theta(x, y) = arctan\frac{f_x(x,y)}{f_y(x,y)} \quad (3)$$

(2) Histogram Generation

According to the above calculated gradient magnitude and gradient direction, the histogram of each cell is generated. As appeared in Figures 3.4, the gradient orientation is sectioned with as a bin in a Cell, and total 9 bins are procured. Four Cells similarly partition from a block are independently accumulated to create four 9D vectors, which are combined into a 36D vector v.



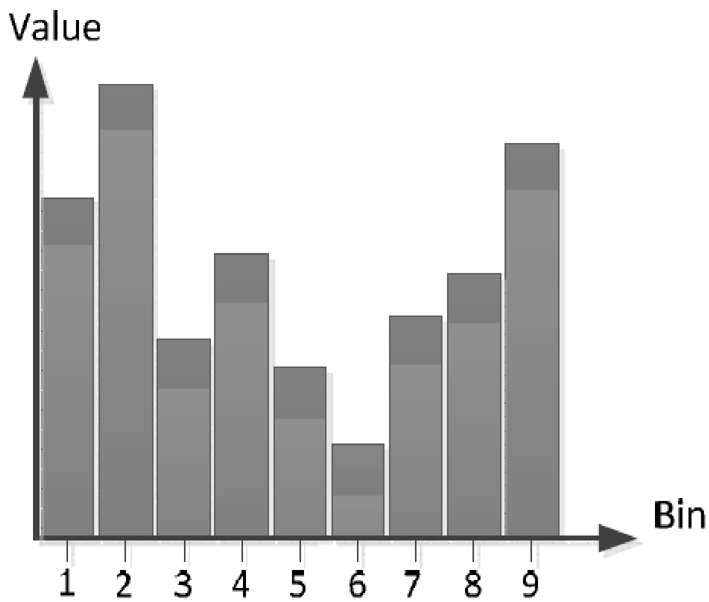


Fig 3.4 Orientation Bins in HOG and an example of HOG for a Cell

(3) Block Normalization

Because of the decent variety of the difference in illumination condition and the background of picture, the range of the gradient value is wide. So the good normalization is important for the detection after feature extraction. Normalization is done by dividing the feature vector ν by L2-norm,

$$\nu \to \frac{\nu}{\sqrt{\|\nu\|_2^2 + \varepsilon^2}} \quad (4)$$

Where ε is a small constant restraining divisions by zero which is generally 1. ν is normalized vector.

(b) Feature extraction using Gray Level Co-Occurrence Matrix (GLCM)

Texture gives important information in an image which can be beneficial in recognition of that image in an automatic recognition system. Texture is property or structure of the surface which is defined as something that consists of mutually related elements. By repetitive appearance of primitive elements either periodic or semi-periodic, we get texture. Texture provides very important information about roughness or smoothness of surface and also gives regularity in the surface. Some of the examples of images of different images are given below in fig 3.5.

GLCM is one of the techniques which are used to extract information of texture of an image. Its advantage is that it not only gives the variation in the pixel values but also provides relative positions of the pixels. There is a position operator 'P' in GLCM which helps in providing relative position of the pixels. To generate GLCM feature a matrix 'A' of dimension G × G is generated using constraint specified by the position operator 'V' where 'G' is the gray level values in the original image. Elements 'a' in matrix 'A' indicate number of times points with intensity value z_j occur at a position determined by 'V' in relation to points with intensity z_i. Let us assume an image 'I' whose co-occurrence matrix has to be calculated and position operator 'V' is defined as one pixels to right. Image 'I' has only 3 different intensity levels i.e. $z_0 = 0, z_1 = 1 \; and \; z_2 = 2$ which will make matrix 'A' of dimension 3 × 3.

$$I = \begin{bmatrix} 0 & 0 & 0 & 1 & 2 \\ 1 & 1 & 0 & 1 & 1 \\ 2 & 2 & 1 & 0 & 0 \\ 1 & 1 & 0 & 2 & 0 \\ 0 & 0 & 1 & 0 & 1 \end{bmatrix}$$

Now matrix 'A' is calculated from matrix 'I' following position operator 'V'.

$$A = \begin{bmatrix} 4 & 4 & 1 \\ 4 & 3 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

If we take sum of the elements of matrix ‘A’ which will come as 20 and then divide matrix ‘A’ with 20 then the matrix formed i.e. ‘P’ is the co-occurrence matrix which is used to calculate features.

$$P = \frac{1}{20}[A]$$

Fig 3.5 Images with different textures

Various parameters of GLCM are calculated using the equation s given below which are further used to calculate features:

$$\mu_x = \sum_{i=0}^{G-1} i\, P_i(i) \text{ and } \mu_y = \sum_{j=0}^{G-1} j P_j(j) \qquad (5)$$

$$\sigma_x^2 = \sum_{i=0}^{G-1} (P_x(i) - \mu_x(i))^2 \tag{6}$$

$$\sigma_y^2 = \sum_{i=0}^{G-1} (P_y(j) - \mu_y(j))^2 \tag{7}$$

Where G is the number of gray level in the original image, μ is the mean of P and $\mu_x, \mu_y, \sigma_x\ and\ \sigma_y$ are the means and standard deviations of $P_x and\ P_y$ respectively. $P_x(i)$ is the i_{th} entry obtained by adding the rows of $P(i, j)$.

By using the above equations, different texture features can be calculated for classification or matching purposes. The details of the features are given as follows:

(a) Contrast

Contrast gives the difference in the luminance or color which makes an image distinguishable. Contrast is calculated using the following equation:

$$\text{Contrast} = \sum_{i,j=0}^{G-1} (P_{i,j}(i - j))^2 \tag{8}$$

Contrast increases with increase in the value of (*i*-*j*) and there is no contrast if *i* becomes equal to *j* i.e. *i*-*j*=0 and it decreases with decreasing value of (*i*-*j*).

(b) Correlation

Correlation gives mutual connection between two pixels in an image. For sake a perfectly positively or negatively associated picture, the correlation value is 1 and - 1.On sake of picture with constant pattern of pixels, its value is NaN. Its range of value is [-1,1] and it is calculated using the following equation:

$$\text{Correlation} = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \frac{\{i,j) \times P(i,j) - \{\mu_x \times \mu_y\}}{\sigma_x \times \sigma_y} \qquad (9)$$

(c) Energy

Energy is defined as the sum square of the pixels in an image. Its range is [0 1].For image with constant pattern of pixels, its value is 1. It can be calculated using the following equation:

$$\text{Energy} = \sum_{i,j=0}^{G-1} \left(P(i,j)\right)^2 \qquad (10)$$

(d) Homogeneity

It gives the calculation of the same kind of pixels in an image. It can be calculated by using the following equation:

$$\text{Homogeneity} = \sum_{i=0}^{G-1} \sum_{j=0}^{G-1} \frac{1}{1+(i-j)^2} P(i,j) \qquad (11)$$

Features calculated using both HOG descriptors and GLCM descriptors are then concatenated to form a single feature vector for matching purpose.

3.2.3 Matching of sketch with photo

It is troublesome and inefficient to match sketch with photograph directly that is the reason feature extraction becomes possibly the most important factor. Features help in giving great outcomes as well as it diminishes the time utilization and complexity cost.

Feature vector calculated from the above techniques are used to match sketch with correct photo and **Euclidean Distance** has been used for that purpose as it is the simplest way of matching two photos with minimum complexity cost. Euclidean Distance can be calculated using the following equation:

$$\text{Distance} = \sqrt{\sum_{i=1}^{n}(\nu_{si} - \nu_{pi})^2} \tag{13}$$

Where ν_s and ν_p are sketch feature vector and photo feature vector respectively and n is the number of features in both the feature vector.

Then the feature vectors having minimum distance are considered to be matched and photo corresponding to given sketch having minimum distance has been declared as the correct match.

Chapter 4

Results and Analysis

4.0 Experimental setup

In this section, technologies and database used in this project for sketch face matching has been discussed.

4.0.1 Database used

As discussed in section 1.1, viewed sketches have been used in the project for the experiment. Viewed sketches are available in an open store (accessible free on the web), from where we downloaded and tried them. The viewed sketches, as a cluster of sketch-photographic sets, were gathered from CUHK face sketch database [2] where 188 sets were gathered. Therefore, we had 188 sets of viewed sketches that are accessible with us. Along with the sketches, we gathered the photographic sets of the relating sketches.

4.0.2 Technologies used

The technologies that have been utilized for every one of the tests stated in this thesis and the ones that have been directed as a major aspect of the research work are appeared in Table 4.1:

Table 4.1

Technologies used

Operating system	Windows 7
Processor	AMD A8-5550M APU with Radeon(tm) HD graphics 2.1 GHz
Software used	MATLAB 2017a

4.1 Results

Experiments were conducted on the available database and they will be discussed in subsequent sections:

4.1.1 Pre-processing

The images available in database i.e. both sketches and photos are already cropped and having size 250×200 (as provided by the standard dataset used). As both the images are not in the same domain of intensity, they have been converted into gray images as shown in fig 4.1. Fig 4.1 also gives the output after processing images with media filter.

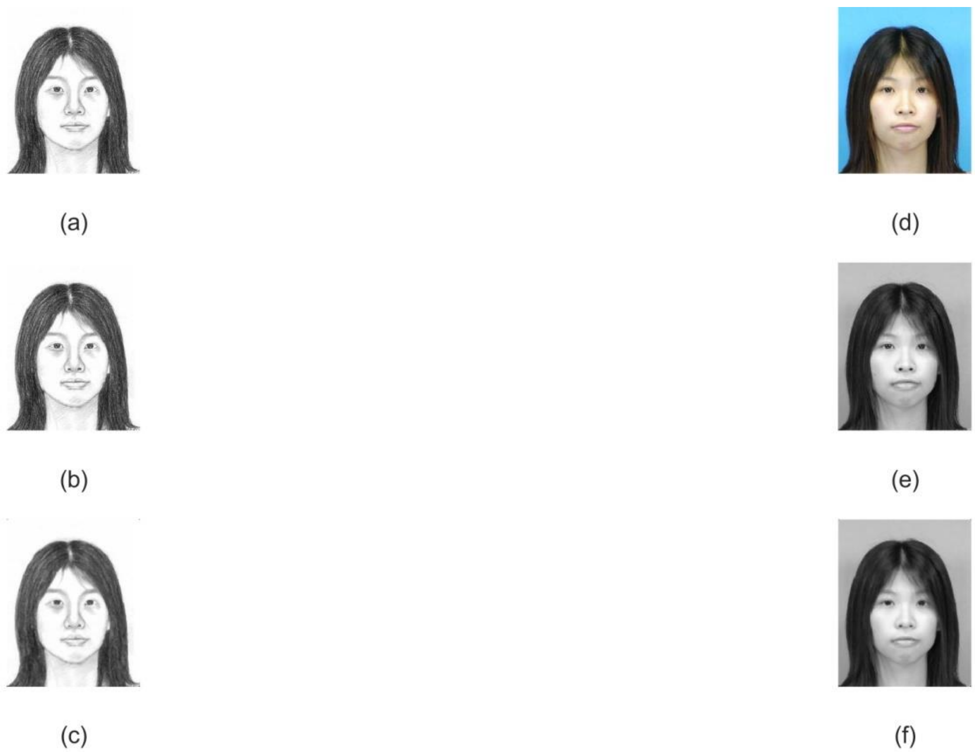


Fig 4.1 (a), (b) and (c) are showing original sketch, gray converted sketch and median filtered image respectively and (d), (e) and (f) showing original photo, gray converted photo and median filtered image respectively.

4.1.2. Feature Calculation

Features have been calculated using two different feature descriptors i.e. HOG and GLCM descriptors and features calculated have been discussed as follows:

(a) HOG features

Hog features in our experiment have been calculated block wise by using different block sizes i.e. 32x32, 16x16 and 8x8 block sizes respectively for both the sketches and photos which are giving different matching Rank-1 accuracies which will be discussed in the next section and it has been found that maximum matching accuracy has been given with 8x8 block size. Number of features calculated for different block sizes are shown in table 4.2.

Table 4.2

HOG features calculated for various block size

Block Size	32×32	16×16	8×8
Number of features	1,080	5,544	25,920

(b) GLCM features

GLCM features gives information of the texture of an image and in a face image, the texture varies mainly in key features of the face e.g. eyes, nose and mouth. So, in our experiment key features have been extracted first from the images and then GLCM features discussed in section 3.2.2 (b) have been calculated. 3 key features from the face i.e. eyes, nose and mouth have been extracted as shown in fig. 4.2 and 4 features for each key feature have been calculated which gives a feature vector of total 12 features.

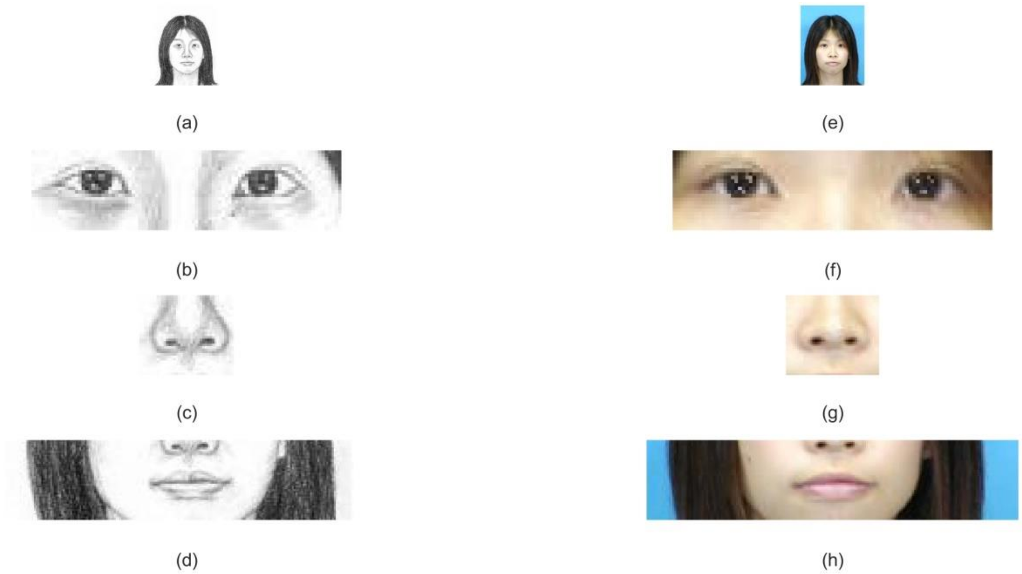


Fig.4.2 (a), (b), (c) and (d) showing original sketch, eyes, nose and mouth extracted respectively and (e), (f), (g) and (h) showing original photo, eyes, nose and mouth extracted respectively.

Both the HOG features and GLCM features have been concatenated to form a single feature vector of length 25932 (i.e. 25920 HOG plus 12 GLCM features) for each image.

4.1.3 Sketch to face matching

Sketches have been matched with photos using above feature vectors and it has been found that Rank-1 accuracy varies with the block size used in HOG which has been shown in table 4.3. Also, accuracy (both Rank-1 and Rank-5) calculated in this project has been compared with some state of the art methods like PCA/LDA+ Geometric information (wavelet method) [12], PCA (Eigen face features) [12], PCA (DCT normalization features)[12], Canonical correlation analysis (CCA) [18] and Partial least squares (PLS) [19] and it has been found that 181 out of 188 images are correctly matched and 7 are wrongly matched for Rank-1 accuracy in our project which is giving better result than the other methods especially in **Rank-5 accuracy that is showing 100 % matching (188 images matched out of 188 available images in database)**. Comparison is shown in table 4.4. Also correct and incorrect matches have been shown in fig. 4.3.

Table 4.3

Rank-1 accuracy of proposed method for various block size used in HOG feature calculation

Block size in HOG feature calculation	**Number of features**	**Rank-1 Accuracy (%)**
32×32	1,080	82.98
16×16	5,544	94.7
8×8	25,920	96.3

Table 4.4

Rank-1 accuracy comparison of proposed method with other methods

Methods	**Rank-1 Accuracy (%)**
Shivaleela. Patil and Dr. Shubhangi, PCA/LDA+ Geometric information (wavelet method)	94
Shivaleela. Patil and Dr. Shubhangi, PCA (Eigen face features)	86
Shivaleela. Patil and Dr. Shubhangi, PCA (DCT normalization features)	86
H. Hotelling, Canonical correlation analysis (CCA)	94.6
Sharma, A. and D.W. Jacobs, Partial least squares (PLS)	93.6
Proposed method	96.3

Chapter 5

Conclusion and Future scope

A novel approach for matching of the viewed sketches with the photos has been introduced in this thesis. In most of the previous work on this field, only one feature descriptor has been used for matching sketches and photos. But to overcome their performances, we have used hybrid of two different types of feature descriptors i.e. HOG descriptors and GLCM descriptors which is giving better result than many state of the art methods with lower time consumption and lesser computational cost.

Future work can be extended by using a good feature reduction method to further reduce time consumption and computational cost which can also improve the accuracy. Also this method can also be implemented on forensic sketches if its database is available online.

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