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Improving Hough Transform for Face Recognition

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ABSTRACT

The use of Hough Transform (HT) on face recognition is a new research in the field of biometrics and computer vision. There exists complexities in applying the Hough transform on face features due to large dimension that is beyond the power of the algorithm. The algorithm was improved and tested using Template Matching. However, the experimental results on FEI, ORL and Yale face databases demonstrated the effectiveness of the technique and recognition was achieved with minimal error. The research aimed at improving HT for face recognition by avoiding complexities involved.

Keywords: Face recognition, Detection, HT, and Template matching

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INTRODUCTION

Face recognition is the process of identifying or verifying a person in question by comparing input faces with face images initially stored in a database. It is one of the most popular physiological biometrics due to its unique characteristics and scored the highest similarity [1]. Face recognition has increased significantly over the past 30 years. The recognition of faces has become a major research area, since traditional means of authentication such as passwords and ID cards are no longer reliable, nor are they convenient enough.

Although other biometric authentication methods based on physiological characteristics such as fingerprints, iris patterns, and hand geometry can be used, but need cooperation of the users. Whereas, authentication using face is intuitive and does not have to rely on user’s cooperation. Face recognition offers interesting services with considerable application to age, size and complexion [2]. It is however, non-intrusive, and perhaps the most natural way of identification. It is essential for interpreting facial expressions, intentions, human emotions, and behaviors, which need prediction in smart environments. Most of the analysis of profile or frontal face images is effective without the knowledge or cooperation of an individual. Application areas for face recognition technology are broad, this includes identification for law enforcement, access control to secure computer networks and facilities such as government buildings, authentication for secure banking and financial transactions, video surveillance usage and automatic screening at airports for known terrorists. Such applications range from static matching of controlled format photographs to real-time matching of video image sequences.

Hough Transform (HT) is one of the feature extraction techniques used in image analysis, computer vision and digital image processing [3]. The use of the transform to detect straight lines in digital images is probably one of the most widely used procedures in computer vision [4]. Factors such as illumination, pose, and size of an image make it difficult to accurately extract faces, especially from a video. These challenges generally make recognition task even more difficult and cause serious performance degradation. Therefore, HT is improved in this paper because of the following reasons:

- The essential feature of HT is that, it is invariance to image scaling, rotation and partially invariance to illumination.
- Although HT has been in existence for the past 51 years of discovery, it is still a lively topic of research and applications. Beside its widespread applications in pattern recognition and image processing, there exists scope for

further research on speed, accuracy and resolution of shape detection especially for complex curves in 2-D and 3-D images [5]. However, only few methods have been proposed for face recognition using HT as explained below.

RELATED WORK

Feature extraction for the purpose of face recognition using HT has recently received increasing attention, to provide an efficient way of authentication. Arindam et al. [6] investigated the performance of HT for face recognition. The research introduced a face recognition using integrated peaks of the HT obtained from significant blocks of the binary gradient image. The gradient of an image was calculated and a threshold was set to obtain a binary gradient image, which is less sensitive to noise and illumination changes. Thus, dimension of the image was reduced. HT was applied on the significant blocks. Then, the best fitted Hough peaks were extracted and concatenated together to form the new features.

A Hough voting-based method was presented in [7] to improve the efficiency and accuracy of fiducially point's localization, which could be integrated for final face alignment. Specifically, few stable facial components such as eyes and nose were first localized from a given face image and fixed as anchor points. Then, these locations were used to reduce the ambiguity encountered when locating other less stable facial feature points. A separate local voting map was constructed for each fiducial point using kernel density estimation, to allow for effective search region of fiducial points. Other methods were used to increase the robustness of the approach.

Nevertheless, computing the HT on the binary gradient image and selecting the significant blocks in [6], requires several iterations. In an attempt to improve this method, another face recognition algorithm based on histogram features of HT peaks was developed by Amrita and Ghose [8]. HT peaks were utilized to determine the orientation angles. The images were divided into non overlapping blocks of equal size, each block was converted into binary, and the HT of each block was computed. Several Hough peaks were detected and the first 30 Hough peaks were retained. Orientation angle corresponding to the 30 retained Hough peaks were selected. Then, orientation histograms were computed from each block. The histograms obtained were concatenated to form the final feature vectors, and classification was achieved using k-nearest neighbour classifier. The results were compared to other state of the art methods.

Reportedly, not only the normal angle and distance of a line can be extracted using HT, but also the line-segment's length and midpoint (centroid) by analyzing the voting distribution around a peak in the Hough space [9]. For recent HT framework, interested reader should see 'A block-wise face feature extraction technique' proposed by Varun et al. in [10]. The binary image was divided into a number of smaller blocks, to separate the region of interest. The size of the block reduces when the number of divided blocks is large, since the image content present in the block is also reduced. This leads to better feature extraction. Then HT was applied, and a number of peaks were obtained. These peaks vary for different blocks of the image. Thus, a set of prominent peaks were selected to maintain constant gallery size. The local maxima were considered as the prominent peaks and their positions were determined. Variations in pose, illumination, expression were also considered. In addition, the experimental results were obtained within an average of 10 iterations. Table 1 summarizes the most recent transforms developed in the literature with their performance comparisons.

The preprocessed image was obtained and partitioned into a set of blocks. HT was applied to each block and Binary Particle Swarm Optimization (BPSO) based feature selection algorithm was used to extract a particular number of prominent peaks. Then, similarity measurement was computed using the Euclidean classifier to measure between the test vectors and the reference vectors in the face gallery.

Table -1 Comparison of HT with Few Transform Based Algorithms

Algorithm	Database	No. of Training Images	Recognition (%)
BGI + HT [6]	ORL	Not specified	95.00
DWT based Algorithm [11]	ORL	1	71.20
	Yale	1	67.50
FMT based Algorithm [12]	ORL	1	68.00
	Yale	1	65.00
Orientation Histogram based Algorithm [8]	ORL	1	80.00
	Yale	1	94.00
Block-wise Hough Transform Peaks (BHTP) [10]	CMU PIE	2	96.88
	Color FERET	8	80.81
Local Hough Voting [7]	BioID	Not specified	98.95

Although HT requires significant storage and has high computational requirements, it is faster and delivers the same result as that of Template matching. It defines a mapping from the image points into an accumulator space (Hough space). This is achieved in a computationally efficient manner, based on the function that describes the target shape. Among all existing shape extraction techniques, HT is the most popular. This is because, HT is equivalent to Template matching. This is the prime advantage of HT [13]. Additionally, the reason why HT needs to be improved is that**,** the number of HT peaks obtained from each image vary, and this leads to redundancy during feature extraction. Similarly, the number of peaks extracted from each segmented block is dependent on the block image size [10]. This means that, difference number of peaks is present across the images. As a result, the process of extracting equal number of peaks in the images, identifying the prominent peaks and extracting a particular number of prominent peaks is time consuming. Meanwhile, it involves a number of iterations.

Contrary to these approaches, an enhanced HT framework is presented in this thesis without dividing the image into blocks, and Canny is used instead of Sobel edge detector as used in [10]. This problem is addressed in this study, since application of HT on face extraction will even be more complicated. Because, face varies from one person to another due to race, gender, age, and other physical characteristics of an individual. It also varies in scale, orientation, pose, facial expression, and lighting condition. Thus, it becomes more challenging since HT locates shapes in images that are represented into set of parameters. The HT is employed with Template matching for efficient face recognition. Template-based approach is a simple process that has been widely employed to locate the human face in an input image. However, this method is very sensitive to pixel misalignment in sub-image areas and depends on facial component detection [14].

RESEARCH METHODOLOGY

To develop the new framework using Hough transform, following important stages were implemented.

Image Databases Used

For detailed evaluation of the proposed framework, three research databases were used for testing, these are: Fédération Equestre Internationale (FEI), Olivetti Research laboratory (ORL) and Yale face databases. Generally, comparing the performance of face algorithms is difficult, partly due to lack of commonly adopted benchmark dataset [7]. These databases were used in some recent works and that motivated us to perform a fair comparison.

Histograms Conversion

An image was first converted to histogram after it has been preprocessed, such as noise removal using median filter. Image histogram is a plot of the relative frequency of occurrence of each permitted pixel values in an image against the values themselves. It shows information of an image using its contrast and reveals any potential difference in color distribution of the image foreground and background scene components [15]. The histogram plot transforms total pixel of images [16], and it is always a solution to comparison of colors. Conversely, Contrast stretching operates by stretching the range of pixel intensities of the input image to occupy a larger dynamic range in the output image.

For a simple gray-scaled image, the histogram can be constructed by simply counting the number of times each gray-scale value (0–255) occurs within the image [15]. Each 'bin' within the histogram is incremented each time its value is encountered, until the image histogram is constructed.

Image histogram was plotted in Mat lab simply using imhist() function. Histogram plot with two distinctive peaks shows that a high peak in the lower range of pixel values corresponds to the dark pixels of an image, and a lower peak in the higher range of pixel values corresponds to bright pixels of the same image. The equivalent histogram distributions of Fig. 1 are displayed in Fig. 2 showing the effect of histograms on contrast stretched image. The histogram converted the enhanced image into histogram bins for easy extraction.

Histograms Rotation

After the range of pixel intensities of the preprocessed image was normalized by enhancing the intensity (often called Contrast stretching), then equivalent histogram of the normalized images were obtained using histogram plot function. This resulted to a distributed histogram of separated bins that is easy to extract the features and minimizes error during matching. In addition, the histogram plots were rotated by 30 degrees to prevent a distorted Hough matrix and guarantee appropriate peaks, meanwhile increase the speed of detection. On the other hand, taking a histogram plot of a rotated image lowers the bins and reduces display time of the plot. In Mat lab, image histogram can be simply rotated using imrotate() function. The rotation was carried out on the histogram plots through the origin which generated another plot of linearly represented features.

The rotation took place like sectioning of histograms plot, which displayed the reduced number of features of an image equivalent to the number of histogram bins. Feature integration implies taken only dominant features that represent the image, using sequential selection through the center of histogram bins. These features were aligned. Aligned features are the integrated features aligned in linear order, so that the extraction process takes a pattern of flow. It eased the extraction process and enabled detection of face features appropriately. However, only one Hough peak was produced in the Hough space. Therefore, several iterations in retaining certain number of peaks were avoided, and complexity of block partitioning was eliminated. This type of rotation is unique in this domain, and contributes largely to the design of the framework. The rotation is simple but effective means of dimensionality reduction. Hence, new features were generated. Fig. 3 illustrates the process of histograms rotation.

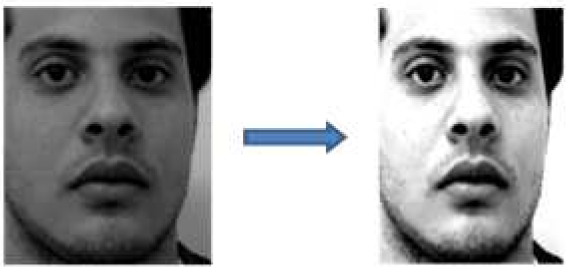

Fig. 1 Contrast stretching applied to a sample image

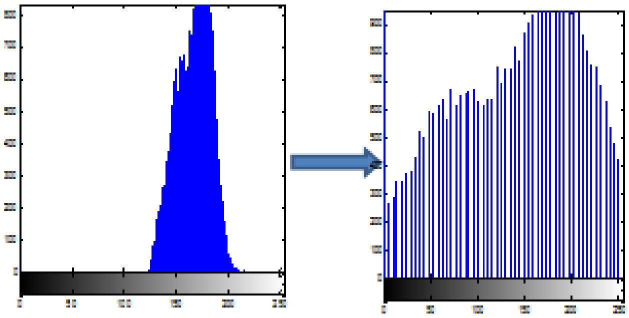

Fig. 2 Before and after histogram distributions of a face image

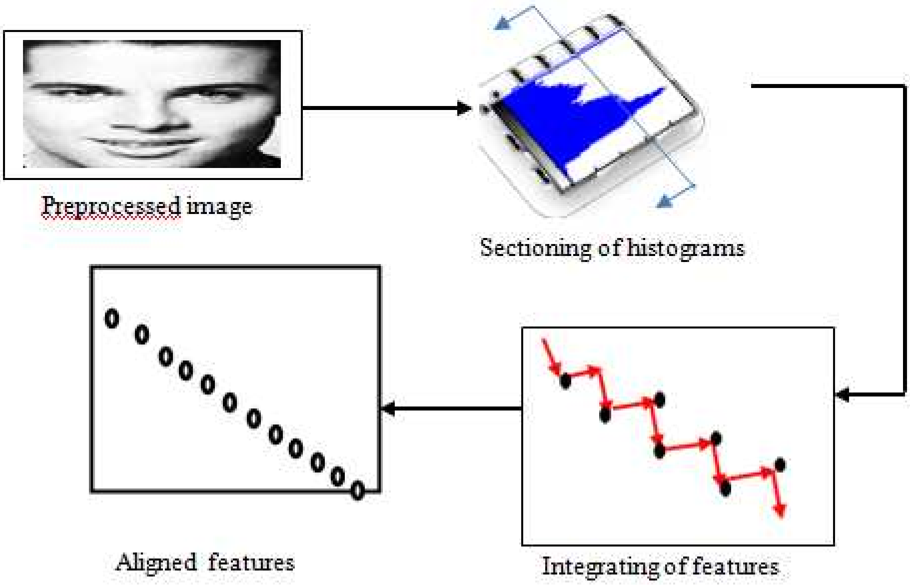

Fig. 3 Histogram rotation process

Application of Canny Edge Detection

An edge is a curve that follows a path where the intensity changes rapidly in an image. Edge detection is used to identify the edges in an image using appropriate edge function. The function looks for places where the first derivative of the intensity is larger in magnitude than some threshold, or it looks for places where the second derivative of the intensity has a zero crossing. The Canny method used in this paper is generally acknowledged as the best 'all-round' edge detection method developed to date [15]. It can easily detect strong and weak edges, and it is less sensitive to noise. This argument was confirmed by applying popular used edge detectors (Prewitt, Sobel, and Canny) on a face image from Yale database, and the effect of Canny was noticed best, since it detects all the varying pixels.

Additionally, performance analysis of Canny edge detection for illumination invariant facial expression recognition was conducted by Zankhana and Vikram [17]. Canny worked satisfactorily well, even for images which are normalized through preprocessing technique. It was concluded that, Canny is an efficient method for feature extraction especially in expression recognition. Despite the type of a classifier, Canny works best. It works reasonably well with many databases. The Canny was applied on the gray-scale images prior to computing the HT. After rotating the features obtained from histogram, the Canny was applied on this plot. The method uses two thresholds to detect strong and weak edges, and includes the weak edges at the output only if they are connected to the strong edges. Therefore, this method is more likely to detect true weak edges. Canny aimed to develop an edge detector that satisfies the following three key criteria:

- A low error rate, this is a situation where the edges occurred in images should not be missed and that there should be no response where edges do not exist.

- The detected edge points should be well localized. This means that, the distance between the edge pixels as found by the detector and the actual edge should be minimum.
- There should be only one response to a single edge.

Basic procedure of applying Canny can be summarized in the following:

Step 1: Reduced the image noise
Step 2: Find the edge strength
Step 3: Calculate the edge direction using the given formula
Step 4: Digitize the edge direction
Step 5: Perform non-maximum suppression
Step 6: Track along the remaining pixels that have not been suppressed and threshold the image to identify the edge pixels.

Feature Extraction using HT

Feature extraction is a process whereby redundant data is removed, retaining the data which is most necessary [18]. The important feature called extracted feature is a detailed representation of the original data. Some subset of relevant features are selected from large number of features extracted, this is called feature selection. For this experiment, HT was used for feature extraction. Fig. 4 shows the feature extraction process. It resembles an extraction of a set of collinear point features (a) which are represented in parameter space when slope-intercept parameterization was used (b), and set of sinusoidal curves in parameter plane after ρ–θ parameterization was used (c).

Template Matching

The face recognition procedure compares an input image of unknown face against a database and reports the percentage of a match. In this section, similarity measure using Correlation was employed for the template matching which is a simple learning algorithm, and simplest approach to pattern recognition [4]. In this approach, the query patterns were matched against the stored templates, while rotation and translation were taking into account. Cross-correlation was calculated, then threshold was set from the experiment outcomes and the regions which have less cross correlation values than the chosen threshold was rejected. Example of template faces is given in Fig. 5.

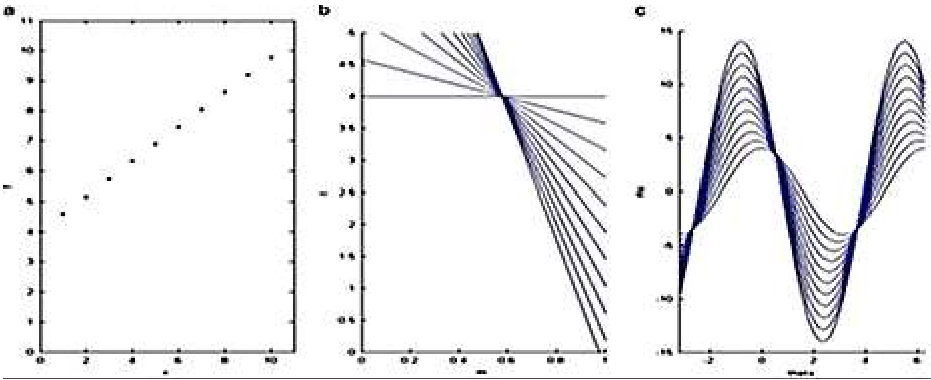

Fig. 4 Feature extraction process [19]

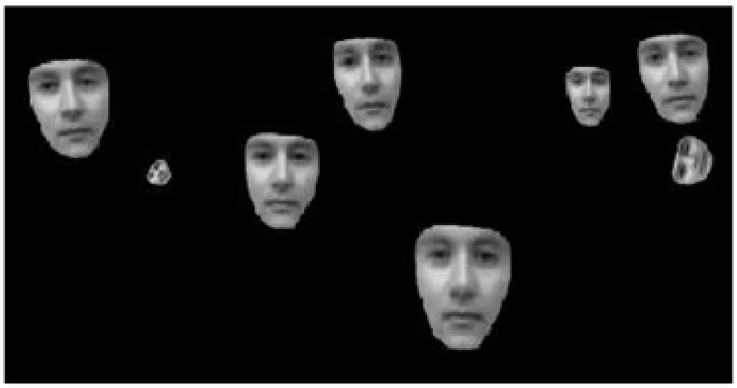

Fig. 5 Template Matching

Cross Correlation Technique (CCT) and Euclidean Distance (ED) were used to compare the similarities of the test images against the neutral image. ED is defined as the straight-line distance between two points. For N-dimensional space, the ED between any two points Ai and Bi is given by:

$$D = \sqrt{\sum_{i=1}^{N} (A_i - B_i)^2}$$

Where Ai and Bi are the coordinates of A and B in the dimension ‘i’ respectively. The smaller the distance, the higher similarity of the test images from the referenced one. While CCT locates features within an image and compares the specific feature in the image, the same way Template matching locates occurrences of shapes in the image. It is given by:

$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}}$$

Where $\bar{A} = \mathtt{mean2(A)}$, $\bar{B} = \mathtt{mean2(B)}$, and r=*corr2*(A,B). The matrix of the extracted features was resized and series of templates were generated. The generated template of each of the neutral face image was matched against the remaining 13 images in each subject to obtain the correlation values as described in Fig. 6. This procedure was used to check the similarity of images from the same subject, such that $A_{neutral}\,x\,A_{remaining}$ were matched, where $A_{neutral}$ stands for a neutral image matched against $A_{remaining}$ (the 13 images of the same subject).

Similarly, the neutral images were further matched with different subjects in the database as shown in Fig. 7 to check the correlation results. This procedure was used to check similarity of images from different subjects, such that $A_{neutral}\,x\,B_{remaining}$ were matched. Where $A_{neutral}$ stands for a neutral image matched against $B_{remaining}$(i.e. 13 images of another subject). These procedures were repeated on all 40 subjects using both CCT and ED to measure the similarity between the images. Suppose ED and CCT are above threshold, the decision is ‘accept’, and if ED and CCT are below threshold, the decision is ‘reject’. The cumulative results of both the CCT and ED were used to make final decision of the verification.

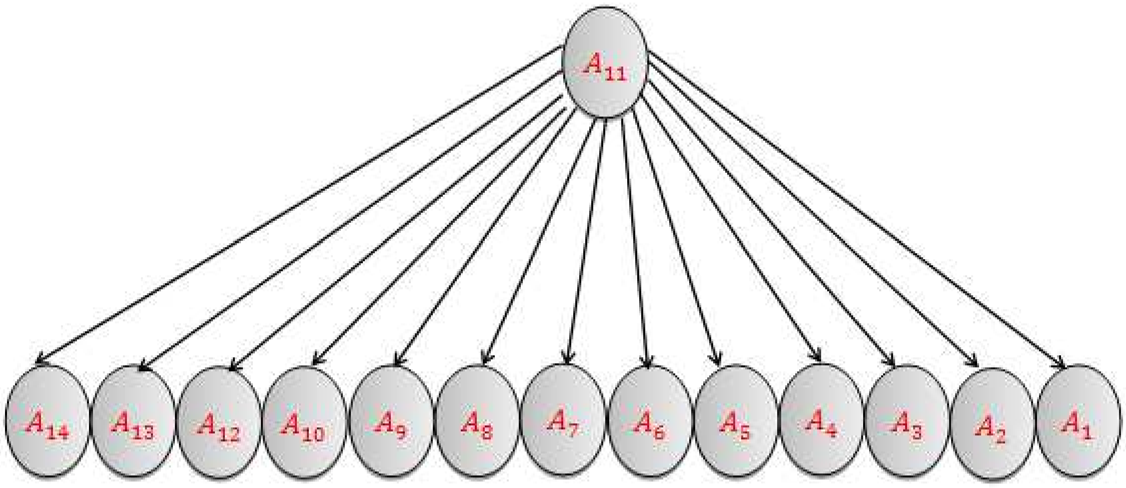

Fig. 6 Matching using the same subjects

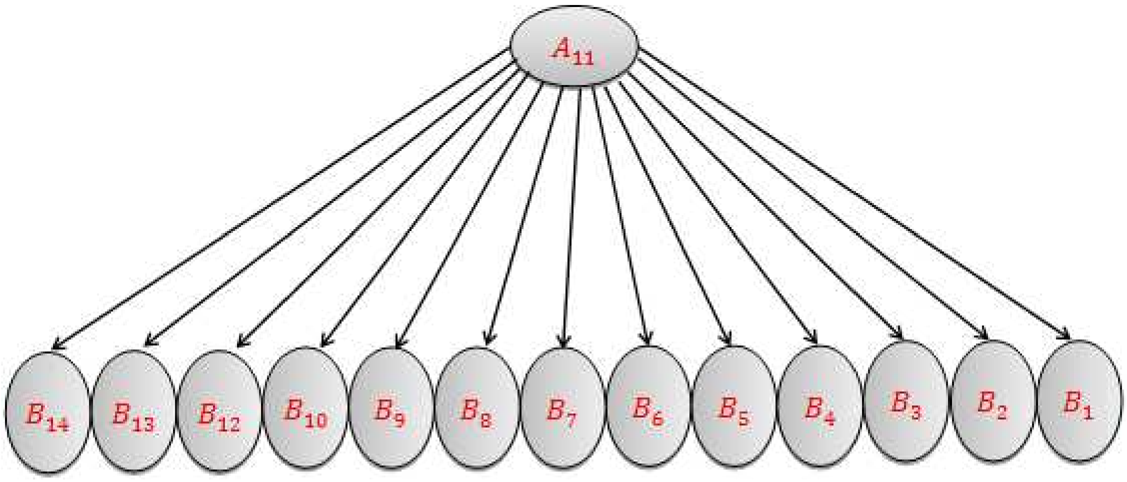

Fig. 7 Matching using different subjects

Implementation Steps

Mat lab implementation adopting the principle of line detection using HT was executed to detect the appropriate features. The process of detecting the face features in this study was implemented using Mat lab functions in the following steps:

Step 1: Read the query image
Step 2: Convert rgb2gray
Step 3: Perform image cropping of 215x250 by means of *imcrop* function
Step 4: Increase the contrast of an image using *imadjust* function
Step 5: Convert the stretched image to histograms using *imhist* function
Step 6: Rotate the histograms plot using *imrotate* function
Step 7: Find the edges in the image using the *edge* function
Step 8: Compute the Hough transform of the image using the *Hough* function
Step 9: Find the peaks in the Hough transform matrix using the *Houghpeaks* function
Step 10: Find linear features in the image using the *Houghlines* function
Step 11: Create a plot that superimposes the lines on the searched features
Step 12: Plot beginnings and ends of linear features
Step 13: Determine the endpoints of the longest linear features segment
Step 14: Highlight the ends of the whole features
Step 15: Display results

RESULTS AND DISCUSSION

For evaluation and comparison of the proposed framework, average recognition results considering both the metrics is 95.63% from FEI, 97.68% from Yale, and 99.97% from ORL face database. Table 2 demonstrates a comparison of the proposed HT with other related algorithms.

The acronym BGI stands for Binary Gradient Image, this approach used HT with selection of 2 nearest to the centroid peaks [6]. Based on the results presented, it is confirmed that the framework produced promising results. This also proved that, with single algorithm it is possible to achieve detection and recognition simultaneously. Hence, the experimental results demonstrated better detection accuracy, and the proposed framework achieved up to 99.97% on ORL face database, which is a significant improvement over the state-of-the-art methods. In addition, the results of this framework proved the essence of modifying the HT algorithm and explored its flexibility on face recognition. This framework resembles Amrita and Ghose (2014) [8], and Varun et al (2015) [10] except that images were not divided into equal sized non overlapping blocks.

Table 2. Comparisons with other Transform Based Algorithms on Benched Mark Databases

Algorithm	Database	No. of Training Images	Recognition (%)
BGI + HT [6]	ORL	Not specified	95.00
DWT based Algorithm[11]	ORL	1	71.20
	Yale	1	67.50
Radon Transform based Algorithm [11]	ORL	1	67.30
	Yale	1	70.00
FMT based Algorithm [12]	ORL	1	68.00
	Yale	1	65.00
Orientation Histogram based Algorithm [8]	ORL	1	80.00
	Yale	1	94.00
Block-wise Hough Transform Peaks (BHTP) [10]	CMU PIE	2	96.88
	Color FERET	8	80.81
Local Hough Voting [7]	BioID	Not specified	98.95
Proposed HT		**1**	**95.63**
	ORL	**1**	**99.97**
	Yale	**1**	**97.68**

CONCLUSION

The improved framework for face recognition using HT was developed in this paper. Where histogram acted as dimensionality reduction technique, and rotation of histogram plots provided new features that can be extracted using HT. The extracted features were used for recognition purpose. The framework was tested using distance measurement and CCT.

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