Automatic Facial Feature Point Extraction by Using Harris Algorithm

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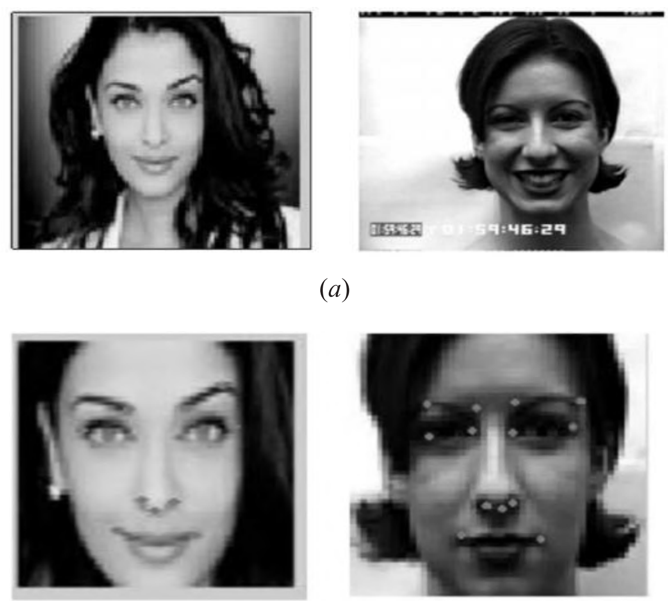
Abstract - **This paper proposes an adaptive algorithm to extract facial feature points automatically such as eyebrows corners, eyes corners, nostrils, nose tip, and mouth corners in frontal view faces, based on Harris corner detection algorithm. This method adopts Viola-Jones face detector method to detect the location of face and also crops the face region in an image. From the concept of the human face structure, six relevant regions such as right eyebrow, left eyebrow, right eye, left eye, nose, and mouth areas are cropped in a face image. The method was tested on a large BioID frontal face database in MATLAB with different illuminations, expressions and lighting conditions and the experimental results have achieved average success rates of 96.15%.**

Keywords: Corner Point Detection, Face Recognition, Facial Features Extraction

I. INTRODUCTION

FACIAL FEATURE extraction is the initial stage of face and facial expression recognition, which is widely used in credit card verification, security systems, identification, authentication, surveillance systems, human-computer interaction, psychology and many more [1]. The most significant facial feature points are eyebrow's corners, eye's corners, nostrils, nose tip, and mouth corners. Face recognition is influenced by many factors such as expressions, lighting conditions on image, variety of postures, size and angle. Even for the same person the image taken in different surrounding may not be same. Due to inter-ocular distance, facial feature for face analysis of eyes are the most crucial points which is unaffected by moustache or beard and constant among people [2, 3]. Next most valuable facial feature point of face is 'nostrils' since nose tip is the symmetry point of both right and left side face regions and nose indicates the head pose and it is not impacted by facial expressions [4]. In recent years several methods for facial feature extraction have been proposed. Well known techniques are principle component analysis (PCA) [5], Linear Discriminant Analysis (LDA) [6], 2D Gabor wavelet [7] and 2D Discrete Cosine Transform (DCT) [8].

Facial fiducial points are usually located on the corners, tips or mid points of the facial components. Associated detection and tracking algorithms for facial fiducial points can be widely used for representing the important visual features for face registration and expression recognition. Fiducial points can be marked manually as shown in Figure 1.



(*a*) (*b*)

Figure 1. (*a*) Unlabelled Images (*b*) Manually Labelled Images with Thirteen Fiducial Points.

However, manual marking of fiducial points is time consuming, tedious and error prone. As such, automation of this process is highly desirable. Some applications of automatic facial feature detection are as follows:-

- *Animation:* Computer generated facial expressions can be animated by tracking features on the human face and replaced with a cartoon like face or some other activity. Therefore, automatic landmarks would be useful in the computer game and film industries etc.
- *Expression Recognition:* Location of fiducial points on the face could be used in the recognition of human facial expressions.
- *Face Recognition:* Landmarks could be used in geometrical

method of face recognition algorithms that identify human beings from still images.

The challenge which makes facial feature detection a difficult task is common to many computer vision problems. Some face specific problems are identity variation, expression variation, head rotation, lighting variation, scale variation, and occlusion etc. Facial feature finding algorithm will fail if any one of these problems exists. Automatic fiducial point detection in still image is useful in many computer vision tasks where object recognition or pose determination is needed with high reliability.

In this paper, an efficient and robust method for facial fiducial point's detection is proposed from an image. This proposed algorithm extracts facial fiducial points automatically from frontal view faces such as eyebrows corners, eyes corners, nose tip, nostrils and mouth corners, which is based on Harris corner detection algorithm [9]. The proposed algorithm adopts the Viola-Jones [10] face detector method to detect the location of face and also for cropping the face region in an image. From the concept of the human face structure, the six relevant regions such as right eyebrow, left eyebrow, right eye, left eye, nose, and mouth areas have been cropped in a face image.

II. PRELIMINARY CONCEPTS

The most widely used methods, which the proposed algorithm has used, are described briefly in this section.

Harris Corner Detection Algorithm: In an image, the corners are the points of common interest and used to get image features for object tracking and recognition. A corner is the intersection of two edges. Harris corner detector [8] is an algorithm based on the local autocorrelation function of a signal, which measures the local changes of the signal with patches shifted by a small amount in different directions. In this algorithm, the autocorrelation function *C(x,y)* is defined as

$$C(x,y) = \sum_W [I(x_i,y_i) - I(x_i + \Delta x, y_i + \Delta y)]^2 \quad (a)$$

where $I(x_i,y_i)$ denotes the image function and (x_i,y_i) are the points in the window W centered on (x, y) and the shifted image is approximated by a Taylor expansion truncated to the first order terms

$$I(x_i + \Delta x, y_i + \Delta y) \approx \left[I(x_i,y_i) + [I_x(x_i,y_i) I_y(x_i,y_i)]\right]\begin{pmatrix}\Delta x\\ \Delta y\end{pmatrix} \quad (b)$$

where $I_x(x_i,y_i)$ and $I_y(x_i,y_i)$ denote the partial derivatives in x and y respectively. The partial derivatives is calculated from the image with a filter like [–1, 0, 1] and $[-1, 0, 1]^T$.

Substituting equation (*b*) in equation (*a*)

$$c(x,y) = [\Delta x\ \Delta y]\begin{bmatrix} \sum_w \left(I_x(x_i,y_i)\right)^2 & \sum_w I_x(x_i,y_i) I_y(x_i,y_i) \\ \sum_w I_x(x_i,y_i) I_y(x_i,y_i) & \sum_w \left(I_y(x_i,y_i)\right)^2 \end{bmatrix}\begin{bmatrix}\Delta x\\ \Delta y\end{bmatrix}$$

Therefore,

$$c(x,y) = [\Delta x\ \Delta y]\, C(x,y)\begin{bmatrix}\Delta x\\ \Delta y\end{bmatrix}$$

where $C(x,y) = \begin{bmatrix} A & B \\ B & D\end{bmatrix}$ and and

$$A = \sum_w \left(I_x(x_i,y_i)\right)^2, \quad B = \sum_w I_x(x_i,y_i) I_y(x_i,y_i), \quad D = \sum_w \left(I_y(x_i,y_i)\right)^2$$

Let α_1 and α_2 be the eigenvalues of *C(x,y)* then there are three cases to consider:

1) When both eigenvalues are high then this will be point of interest (corner).
2) If one eigenvalue is high then this will be contour (edge).
3) When both eigenvalues are small then this will be uniform region (constant intensity).

To find the point of interest, corner response *H(x, y)* is characterized by eigenvalues of *C(x,y) :*

1) *C(x,y)* is symmetric and positive that means α_1 and α_2 are > 0
2) $\alpha_1\alpha_2$= determinant() = $AD - B^2$
3) $\alpha_1+\alpha_2$= trace() = A + D
4) $H_{CornerResponse} = \alpha_1\alpha_2 - k(\alpha_1+\alpha_2)^2$

where:

- $H_{CornerResponse}$ is positive for corners, negative for edges and small for flat regions.
- *k* is the sensitivity factor used in the Harris corner detection algorithm as a scalar numeric value such that $0 < k < 0.25$. The smaller the value of *k*, the more likely the algorithm will detect sharp corners. The default value of k is 0.04. And corner points are local maxima of the corner response.

Viola-Jones Face Detection Algorithm: For the detection of face region, widely used Viola-Jones real time face detector method [10] has been used in the proposed method. Though the training through this method is slow, but detection is very fast. This scheme is made from cascading classifiers trained by AdaBoost algorithm. Integral image filters are employed for each classifier, which is based on Haar functions and it can be computed at any location. This is used to speed up the detection rate. For each stage in the cascade classifiers, a subset of features is chosen using a feature selection procedure based on AdaBoost.

Integral Image

The first step of the Viola-Jones face detection algorithm is to change the input image into an integral image. This is done by making each pixel equal to its value plus entire sum of all pixel values above and to the left of the concerned pixel, as shown in Figure 2.

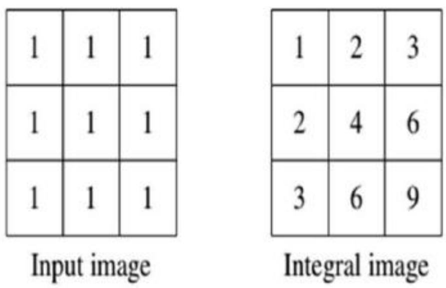
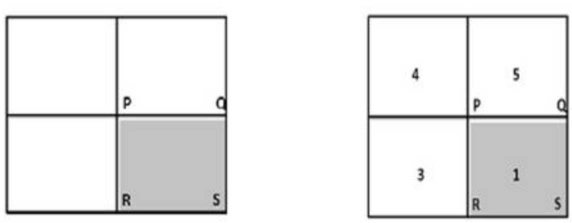


Figure 2. Integral Image.

Let P, Q, R, S be the values of the integral image at the corners of a rectangle as shown in Figure 3 (*a*). Then the sum of original image values within the gray rectangle can be computed: sum = P+S – Q – R

From Figure 3 (*b*), Integral values of P, Q, R, and S are
P = 4; Q = 4+5 = 9; R = 4+3 = 7;
S = 4+5+3+1 = 13;

Therefore, gray rectangle value = 4+13–9–7= 1



(*a*) (*b*)

Figure 3. (*a*) Sum Calculation of Integral Image (*b*) Sum Calculation of Integral Image with Data.

Features of sub-window have been calculated by “two or more rectangles. The different types of features” are shown in Figure 4.

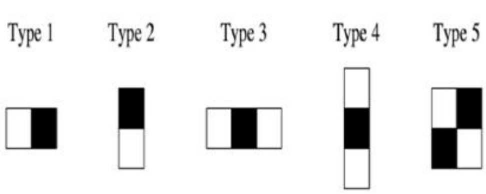
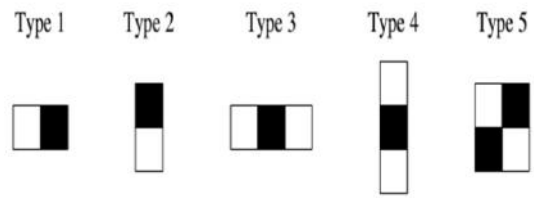


Figure 4. Different Types of Rectangle Features.

Each feature (F) results in a single value which is calculated by subtracting the sum of the black rectangle(s) from the sum of the white rectangle(s).



Cascade Classifier

It is composed of stages and each stage containing a strong classifier. The purpose of each stage is to determine whether a given sub-window is a face or not a face. The sub-window is immediately discarded if it is identified as non-face. Conversely, when a sub-window is classified as a face by a given stage then it is passed on to the next stage in the cascade. The chances of a sub-window containing a face increase, as it moves on to next stage in the cascade. The cascading classifier process is illustrated in Fig. 5.

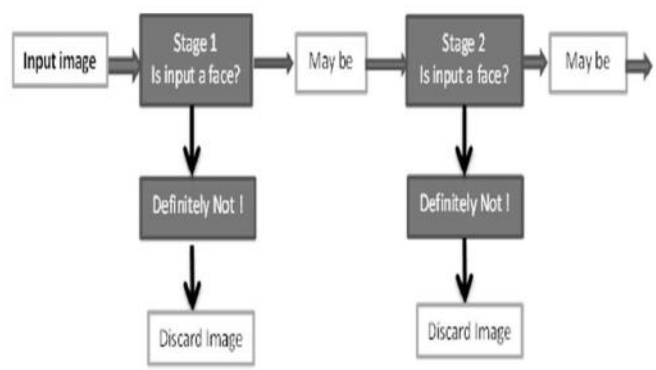


Figure 5. Cascade Classifier.

In a single stage classifier, one would normally accept false negative in order to reduce the false positive rate. However, for the initial stages in the cascade classifier, false positives are not considered to be a problem since the succeeding stages are expected to sort them out. Therefore, Viola-Jones prescribes the acceptance of many false positives in the initial stages. Consequently, the amount of false negatives in the final stage classifier is expected to be very small.

III. PROPOSED METHODOLOGY

The proposed algorithm is organized into three sections as shown in Fig. 6, which includes pre-processing, processing and detection sections. Since the faces are non-rigid and have a high degree of variability in location, color and pose, it is difficult to detect face automatically in a complex environment. Occlusion and illumination of light can also change the overall appearance of a face. It is necessary to normalize the size of the input image in the format required by the system. The steps of the proposed methodology are as follows.

Step 1: In pre-processing section, face detection and its location has been done by applying viola-jones algorithm [11] and also cropping the face regions such as right-eyebrow, left-eyebrow, left-eye, right-eye, nose and mouth in an image has been done.

Let us consider input image I(x, y) is still colour image and resized into 92x92 pixels.
I(x, y) = frontal view image
Face_detection = detection_method (I)
Face_area = crop (Face_detection)

Step 2: After detection of face area, adaptive median filter has been applied to reduce impulse noise level from corrupted images. The median filter is a simple and nonlinear smoothing filter.

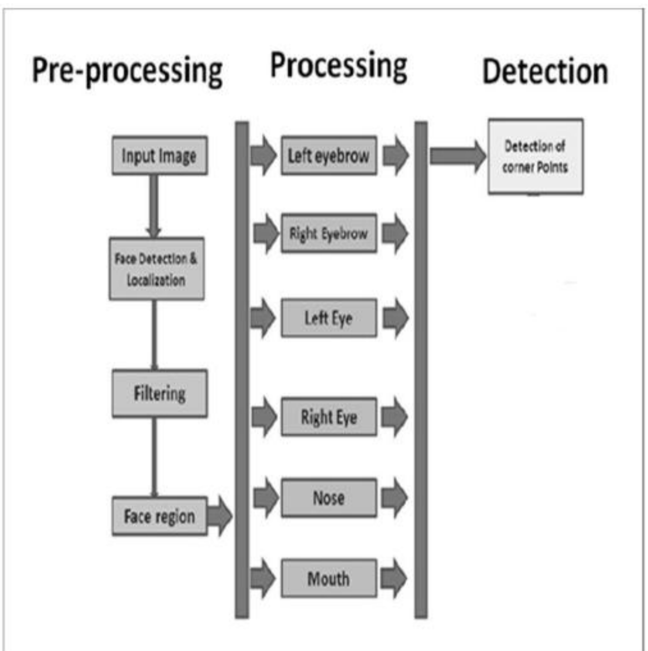


Figure 6. Block diagram of proposed feature extraction algorithm.

Step 3: In processing section, detected face area is converted into gray scale image. From this gray scale image, another six regions has been cropped from this face area *i.e.* left eyebrow, right eyebrow, left eye, right eye, nose and mouth as shown in Fig. 7. This rectangular part describes the detected face area from input image where *H* is a height of face and *W* is a width of face.

Gray_face = rgb2gray (Face _area)
Left_eyebrow = crop (Gray_face)
Right_eyebrow = crop (Gray_face)
Left_eye = crop (Gray_face)
Right_eye = crop (Gray_face)
Nose = crop (Gray_face)
Mouth = crop (Gray_face)

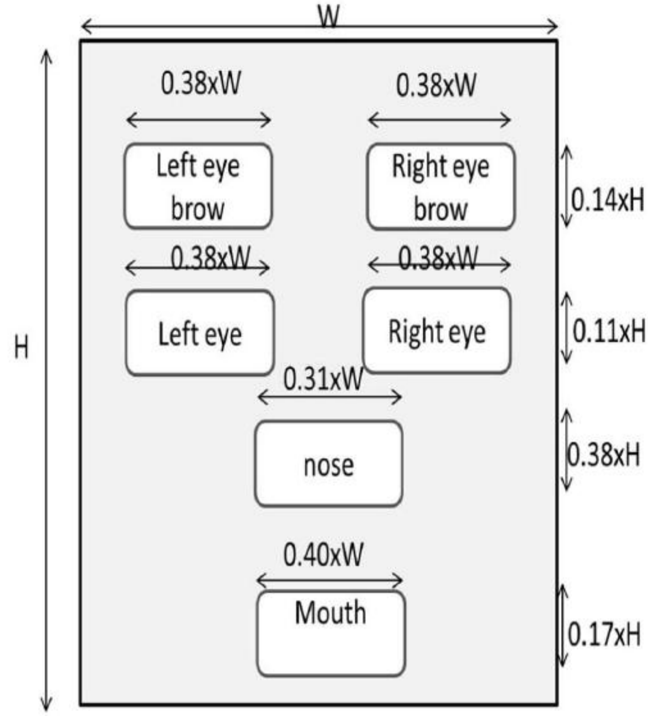


Figure 7. Location and size of objects (*a*) Right Eyebrow (Size: 0.38W × 0.14H), (*b*) Left Eyebrow (Size: 0.38W×0.14H), (*c*) Right Eye (Size: 0.38W × 0.11H, (*d.*) Left Eye (Size: 0.38W × 0.11H, (*e*) Nose (Size: 0.31W × 0.38H) and (*f*) Mouth (Size: 0.40W × 0.17H) where W = Image Width and H = Image Height.

Step 4: In this step, corner points of facial objects have been detected by using Harris corner detection algorithm.

Lefteyebrow_corner = Corner_detection (Left_eyebrow)
Righteyebrow_corner = Corner_detection (Right_eyebrow)
Lefteye_corner = Corner_detection (Left_eye)
Righteye_corner = Corner_detection (Right_eye)
Nose_corner = Corner_detection (Nose)
Mouth_corner = Corner_detection (Mouth).

IV. EXPERIMENTAL RESULTS

Experimentation of proposed technique is performed on BioID database and some personal images. MATLAB is used as simulation tool for experimentation. In BioID database, there are 23 distinct people, with 1521 images of size 384×286 pixels. The images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses). During evaluation, some images are omitted due to :(*i*) detection of false region by Viola-Jones face detector algorthm [11] and (*ii*) person with large size eye glasses or highly dense moustache or beard.

The proposed algorithm is developed for evaluating geometrical feature points of the image, using Harris corner detection algorithm with thresold values. To detect eyebrows corner points, eyes corner points, nose points and mouth corner points. The experimental results are shown in figures 8 and 9 respectively. Original image of object, face detection, cropped image of face area and seven cropped objects of face area are depicted in Fig. 8. And corner points of each objects are depicted in Fig. 9.

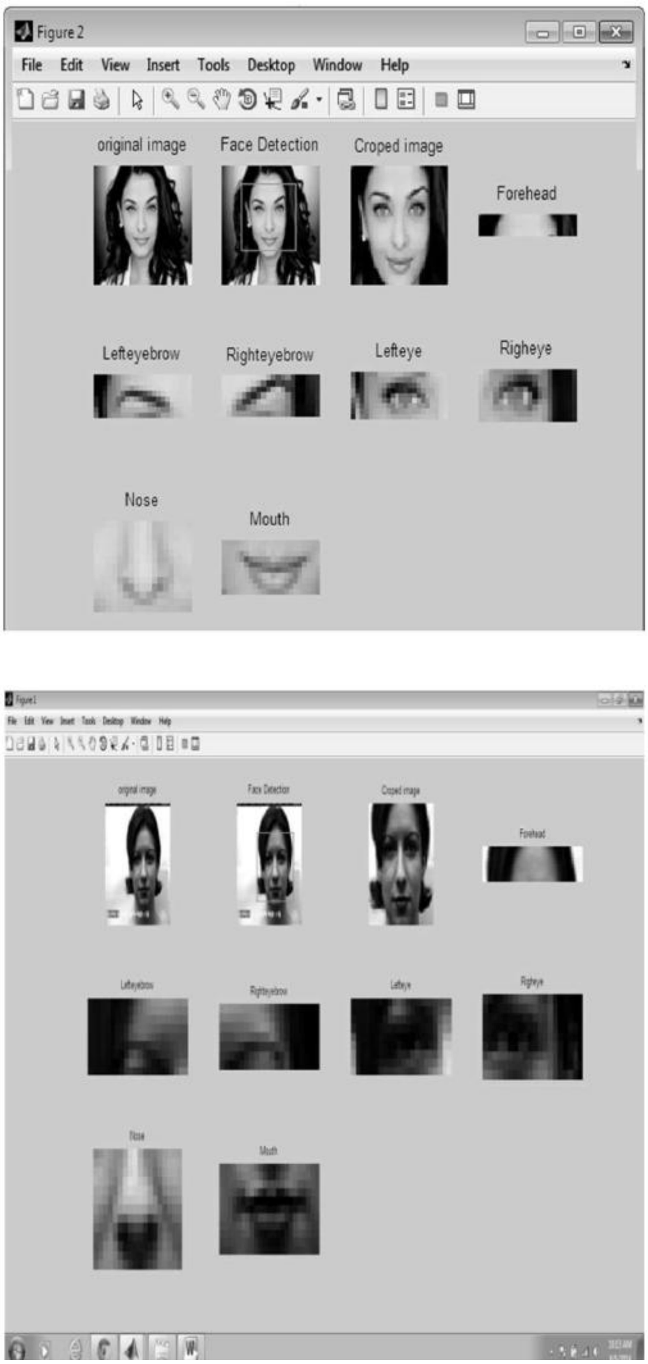


Figure 8. (*a*) Original Image, (*b*) Face Detection and Localization, (*c*) Cropped Face Image and (*d*) Seven Cropped Objects of Face Image.

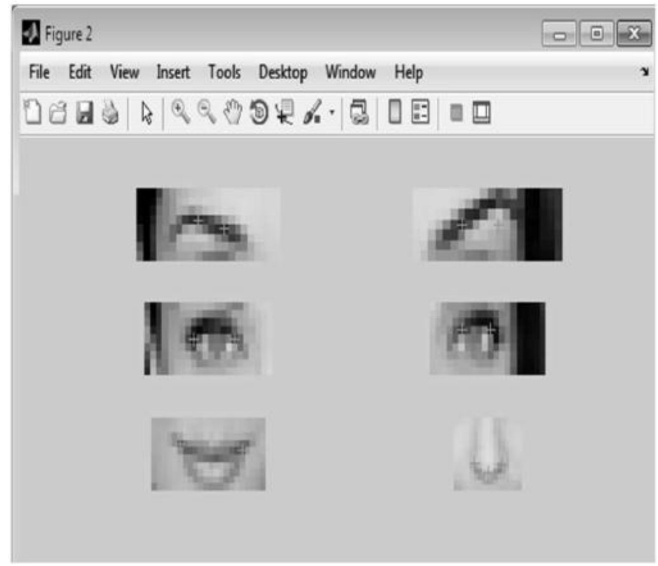


Figure 9. Corner points of each object (Total 13 Corner Points).

Recognition rate of each facial component has been recorded as shown in Table1, and an average recognition rate is 96.15%. It can be observed from Table 2, this proposed method has been compared with other researcher's algorithm *i.e.* two-level hierarchical wavelet network [11], Gabor Feature Based Boosted Classifiers [3] and Cumulative Histogram. The comparison results are shown in Table 2.

TABLE 1–DETECTION RATE OF DIFFERENT OBJECTS

Left eyebrow	Right eyebrow	Left eye	Right eye	Nose	Mouth	Aver-age
93.50	96.50	97.36	98.56	94.52	96.45	**96.15**

TABLE 2–COMPARISON TABLE

Algorithm	Avg. recognition rate(%)
2-level HWN [Feris *et al.,* 2002]	92.87
GFBBC [Vukadinovic and Pantic, 2005]	93.00
Cumulative Histogram [Paul *et al.,* 2012]	95.27
Proposed Method	**96.15**

V. CONCLUSION

Various approaches have been proposed in the past to extract facial fiducial points from face images. The proposed automatic approach to detect facial fiducial points for varying facial expressions, has been established experimentally to handle a certain degree of head rotations and achieved detection rate of 96.15% when tested on BioID face database.

Further, the recognition rate is better than 2-level HWN[12], GFBBC [3], and Cumulative Histogram [12] by approximately 3.28%, 3.15%, and 0.88% respectively.

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