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Face detection and Eyes extraction using Sobel Edge Detection and Morphological Operations

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***Abstract*— Face detection and eyes extraction has an important role in many applications such as face recognition, facial expression analysis, security login etc. Detection of human face and facial structures like eyes, nose are the complex procedure for the computer. This paper proposes an algorithm for face detection and eyes extraction from frontal face images using Sobel edge detection and morphological operations. The proposed approach is divided into three phases; preprocessing, identification of face region, and extraction of eyes. Resizing of images and gray scale image conversion is achieved in preprocessing. Face region identification is accomplished by Sobel edge detection and morphological operations. In the last phase, eyes are extracted from the face region with the help of morphological operations. The experiments are conducted on 120, 75, 40 images of IMM frontal face database, FEI face database and IMM face database respectively. The face detection accuracy is 100%, 100%, 97.50% and the eyes extraction accuracy rate is 92.50%, 90.66%, 92.50% respectively.**

Keywords*— *sobel edge detection, morphological operations, face detection, eyes extraction.

I. INTRODUCTION

The present world of digitalization has a huge usage of the electronic devices that replaces the traditional techniques which need physical presence. Traditional techniques are conventionally secured by identity cards, keys, passwords and personal identification number (PIN). In case of stolen or forgotten, these may lead to theft of personal data. Security of electronic devices, information and premises need a unique, personal protection key that is non-accessible to unauthorized users. Such types of problems can be solved by biometrics [1].

The biometric is a technique used to provide authentication by using the unique physiological and behavioral characteristics of a person. Fingerprint recognition, facial recognition, iris recognition, retina recognition and hand geometry scan are some examples of physiological biometric. Speech recognition and signature scan indicate behavioral biometric [2]. Behavioral biometric are used for verification and physiological biometric are used for both identification and verification [3].

The biometric systems based on face detection and eyes extraction are cost effective as these can use camera which may be webcam or security camera and these are easily available [4]. Face detection plays an important role in face recognition, facial expression analysis, face tracking, facial feature extraction, gender classification, identification system, human computer interaction (HCI) system, digital cosmetics, security login and criminal investigation [5]. Eyes extraction is used for some applications such as security for login purposes, criminal records matching, eye-gaze tracking, iris detection, video conferencing, facial expression detection and human interaction [6].

In this paper, face and eyes are identified by Sobel edge detection technique and morphological operations from color frontal face image which contains single human face. Section 2 describes related work of the face detection and eyes extraction. Section 3 provides information about database used for the experimental purpose. The proposed work is presented in section 4. Section 5 concludes the proposed work.

II. RELATED WORK

Various researchers have been working on face detection and eyes extraction in human face image for two decades due to its numerous applications in various fields. The extraction of eyes from face region was achieved by many researchers while certain researchers extract face region with the help of eyes points. The related work of different face detection and eyes extraction methods are discussed here.

Kawaguchi and Rizon proposed an algorithm in which eyes were extracted by the intensity valley from the face region using edge detections, morphology, region growing algorithm, circular Hough transformation and feature template approaches [7]. The limitation of this algorithm was computationally slow.

Viola and Jones used Integrated image, Adaboost learning algorithm with Haar like features, and combining the classifier in a cascade for face detection [8]. Weak classifier, slow learning method and large number of features were major drawback of this algorithm. Some improvement achieved by Wu and Ai, using morphological operations and YCbCr color space model for skin color segmentation [9].

Shafi and Chung proposed edge-density based method for frontal face image by using the Lightening compassion, histogram equalization, morphological operations and Sobel edge detection technique [10]. In this approach, detection on

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different size images did not work properly due to size of

$$|G| = \sqrt{{G_x}^2 + {G_y}^2} \quad (1)$$

structuring elements.

Rajpathak et al. identified the skin region by six-sigma technique operated on combination of RGB (Red-Green-Blue color model), HSV (Hue, Saturation and Value color space model) and NTSC (National Television System Committee) spaces. The illumination spot between eyes had been detected by morphological operations and this was based on the fact that an eye had a sharp point of reflection whenever it was being properly illuminated [11]. The major drawback of this algorithm was increased complexity due to many color space models.

Bhoi and Mohanty discussed the eyes extraction algorithm based on template matching by cross correlation technique [12]. Desai et al. described an approach using the L*a*b color space for face detection. YCbCr color space and eye map were used in eyes extraction [14]. Eyes region was extracted after face region detection using generic template matching with probable left eye and right eye region by Dutta and Bhattacharjee [15]. Requirement of the eyes template was the limitation of these types of algorithms.

Ito et al. described eyes extraction that used circular Hough transform, evolution of likelihood of eye using histogram and Support Vector Machine [13]. Ashwini et al. extracted eyes circles by circular Hough transform. Noise removal was done by symmetric test, horizontal test, dark pixel test and eye pair distance test [6]. Hough transform used in these algorithms was computationally expensive due to requirement of rough size of pupil and circle fitting.

From the literature, it has been observed that most of the algorithms are computationally expensive. Hence, it further provides a scope to improve the accuracy as well as to have low computational complexity. Considering this, an approach has been proposed for face detection and eyes extraction which is able to handle the frontal images of different size containing face of a single human. The proposed algorithm has the advantages that binary image is used for morphological operations, which is computationally inexpensive and geometry operations are used for extraction of eye portion that reduces complexity. The algorithm is based on Sobel edge detection and morphological operations such as dilation, conditioned dilation, closing and erosion operation. These operations are described as follows:

A. *Sobel edge detection*

2-D spatial gradient measurement on the image is performed by Sobel operator. Each pixel of the image is operated by Sobel operator and measured the gradient of the image for each pixel. Pair of 3×3 convolution masks is used by Sobel operator, one is for x direction (G_x) and other is for y direction (G_y) [19].

G_x

-1	0	+1
-2	0	+2
-1	0	+1

G_y

+1	+2	+1
0	0	0
-1	-2	-1

The magnitude of the gradient is formulated by:
Approximate magnitude is calculated as

$$|G| = |G_x| + |G_y| \quad (2)$$

Direction of gradient

$$\theta = \arctan(G_y/G_x) \quad (3)$$

B. *Morphological dilation*

It is used to grow the region in the input image. Structuring element is used by dilation operation for probing and expanding the shapes. Structuring element is a small binary image with some shape and size, where size determines dimension of matrix and shape specifies a pattern of 1's and 0's [20]. If structuring element S is applied to image A, new image I is

$$I = A \oplus S = \bigcup_{s \in S} A_s \quad (4)$$

C. *Conditioned dilation*

It is based on dilation, intersection and complementation [21]. Let A be a set of 8-connected boundary elements, each boundary enclosing a background. The conditioned dilation is started by creating an array X_0 of 0s which size is same size A.

$$X_i = (X_{i-1} \oplus S) \cap A^c \quad (5)$$

Termination step: $X_i = X_{i-1}$ (6)

Where X_i contains all the filled holes.

D. *Morphological closing*

It is an erosion followed by dilation with same structuring element [22]. The closing operation is

$$A \bullet S = (A \oplus S) \ominus S \quad (7)$$

E. *Morphological erosion*

It is used to shrink the image [23]. The eroded image I is

$$I = A \ominus S = \bigcap_{s \in S} A_{-s} \quad (8)$$

III. DATASETS USED

The proposed work has been tested on three publicly available databases, IMM frontal face database, FEI face database and IMM face database. The IMM frontal face database was recorded in 2005 by Fagertun, and Stegman at Technical University of Denmark. IMM frontal face database consist of 120 images of 12 different human faces. 10 frontal

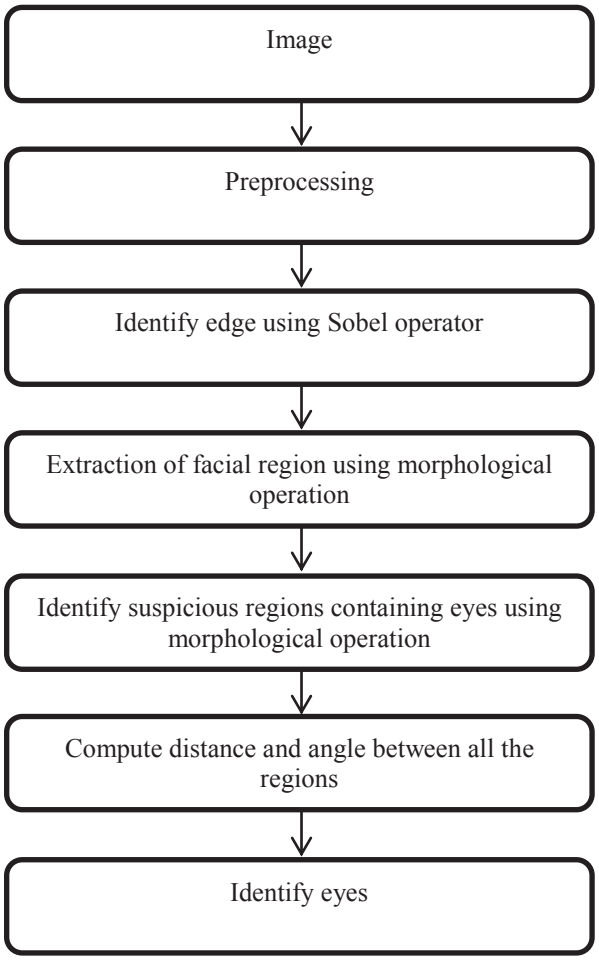
faces of each person are captured with minimum variance of lightening, camera position and different time. IMM frontal database contains images which are without glasses, hat or other accessories and having light color background. The size of each image is 2560×1920 pixels. All persons are male and

Figure 1: Steps for proposed methodology

their age is between 24 to 52 years [16]. The FEI face database was organized in between June 2005 and March 2006 at the Artificial Intelligence Laboratory of FEI in Brazil. FEI face database consist of 2800 images of 200 individuals. It contains 14 color images of each person against a white homogeneous background in frontal position with face rotation of up to about 180 degrees. The size of each image is 640×480 pixels. The database has 100 males and 100 females with distinct appearance, hairstyle and age vary from 19 to 40 years. Randomly frontal images have been taken from database where each subject has two frontal images, one with a neutral expression and the other with a smiling face expression [17]. The IMM face database was recorded in May 2004 by Nordstrom, Larsen, Sierakowski, and Stegmann at Technical University of Denmark. The IMM face database contains 240 images of 40 people in which 33 males and 7 females. The size of each image is 640×480 pixels and in JPEG format. Images with dark color background were taken in different lighting conditions, diffuse light and spot light [18].

IV. PROPOSED WORK

In this paper, the proposed method works in three stages; preprocessing, identification of the facial region, and extraction of eyes. The steps used in the proposed methodology are shown in figure 1.



A. *Preprocessing*

Initially image is resized by 384×288 pixels [8]. Images of different databases may not be of the same size. If the images are of the same size further processing is simpler. Color image

(a) (b)

Figure 2(a) Original image after resizing (b) Gray scale image

is converted to grayscale image as shown in figure 2(b). Gray scale color image is taken as color space model because the edge detection technique is dependent on gray scale image.

B. *Identification of face region*

The gray scale image is further processed for face detection. Edge detection technique has been applied to gray scale image to find the edges of human image in order to separate foreground and background. Maximum intensity variations in the eye region make sharp edges and background of the image is black region. The Sobel operator gives better edges of boundaries, eyes, nose, and mouth [10]. The edges of the image obtained are shown in figure 3(a).

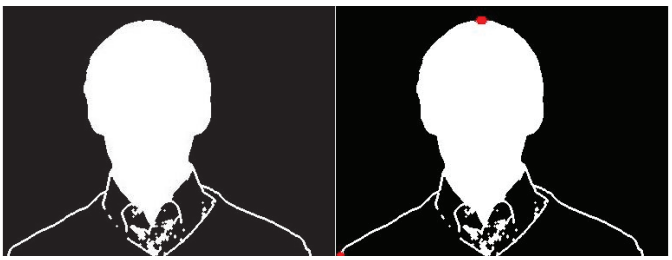
Result of edge detection is a binary image. Edges in this image are thin, therefore morphological dilation is performed on the edged image to thicken the edges as shown in figure 3(b). Disk as structuring element is applied to edged image to achieve dilation.

(a) (b)

Figure 3(a) Edged image (b) Dilated image

The conditioned dilation is applied to this image to fill the region surrounded by connected border giving the face region as shown in figure 4(a). Conditioned dilated image is an image which has a black background with white pixel for the human face.

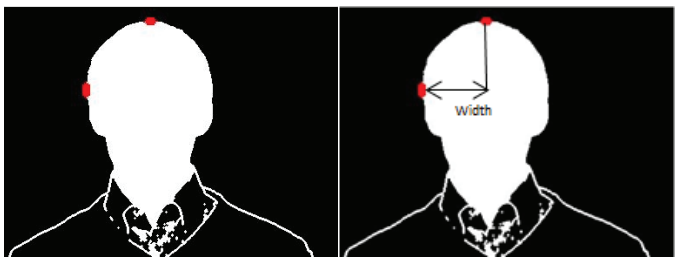
Geometrical operations are performed on the conditioned dilated image, to find the minimum row and minimum column of white pixel for the first row and first column value of the white region in binary image as shown in figure 4(b). If the first row or first column contains more than one value then average value is taken from the first row or first column.



(a) (b)

Figure 4(a) Conditioned dilated image (b) First row and column of white pixel in image

Datasets used by proposed algorithm contain images which include head and shoulder of a human. First full scan of image gives minimum column value which always points to shoulder. Left side of the ear or hair around the left ear is the minimum column value of face that lies in half of the image. Upper half of the image is scanned again to get the required column value. The upper point of the face is given by row and left point of the face is given by column as shown in figure 5(a) and 5(b).



(a) (b)

Figure 5: (a) First row and column for white region in face image (b) diameter for face

Based on the parameter of the row, column, height and width value, the image is cropped to get the face part as shown in figure 6.

Figure 6 Cropped face region image

C. Extraction of eyes

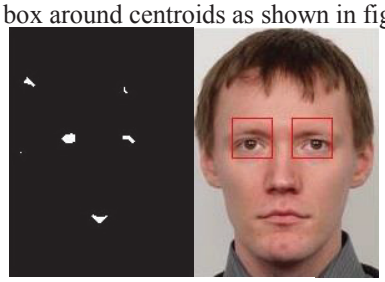
For extraction of eyes, the dilated image as shown in figure 3(b) is processed further. Morphological closing operation with diamond structuring element is applied to dilated image for enlarging the boundary region of foreground and shrink background region. Resultant of closing operation is an image which has white part for eyes region as well as unnecessary white region as shown in figure 7(a).

To this image, erosion operation is performed with disk structuring element to remove boundary part to extract eyes part as shown in figure 7(b).

(a) (b)

Figure 7(a) Morphological closed image (b) Eroded image

This image is cropped considering figure 6 as shown in figure 8(a). The eyes are denoted by white region in the resultant image with some unnecessary white region for lips, hairs and some boundary points. Centroid of white regions in the image is computed for calculation of distance, angle between white areas. Eyes region is decided by distance from left corner or top or bottom to centroid and the angle between the centroids. Eyes are not too close to the boundary of the face image [9]. Eyes of a person in the frontal upright facial image are in a straight line approximately [11]. So, those regions having an absolute angle greater than threshold value (θ) are considered. As per the experimental results on images, it is analysed that absolute angle θ is between 0° to 8°. Corresponding regions (eye regions) in color image are given by bounding box around centroids as shown in figure 8(b).



(a) (b)

Figure 8: (a) Cropped image (b) Resultant image

The proposed work has been tested on IMM frontal face database, FEI face database and IMM face database. 120 images from IMM frontal face database, 75 frontal images from FEI database and 40 frontal neutral face images from IMM face database have been considered for testing. Table 1 shows the accuracy of the face detection. 100% accuracy is obtained in face detection of IMM frontal face and FEI face database. Out of 40 images of IMM face database, 39 images are showing accurate results. Eyes extraction accuracy results on different dataset are shown in table 2. Eyes are shown with the help of bounding box in color face image after eyes extraction. 101 out of 120, 68 out of 75 and 37 out of 40 images are showing the correct result in IMM frontal face, FEI face and IMM face database respectively. Figure 9 shows the images from these three databases for extraction of eyes.

The proposed algorithm works effectively for different types of images. Accuracy of proposed algorithm is not affected by their gender and different hair styles (curly hair, small hair and long hair) as shown in figure 9. Additional advantage of the proposed approach, it gives good result for some facial expression images like normal face expression, smiling face expression etc. It also gives satisfactory results for the images in which neck is slightly tilted. The proposed algorithm works effectively for color image as well as for the grayscale image as shown in figure 9(c).

Database name	Image used	Correct result	Accuracy
IMM frontal face	120	120	100 %
FEI face	75	75	100 %
IMM face	40	39	97.50 %

TABLE I. ACCURACY OF FACE DETECTION

Database name	Image used	Correct result	Accuracy
IMM frontal face	120	101	92.50 %
FEI face	75	68	90.66 %
IMM face	40	37	92.50 %

TABLE II. ACCURACY OF EYES EXTRACTION

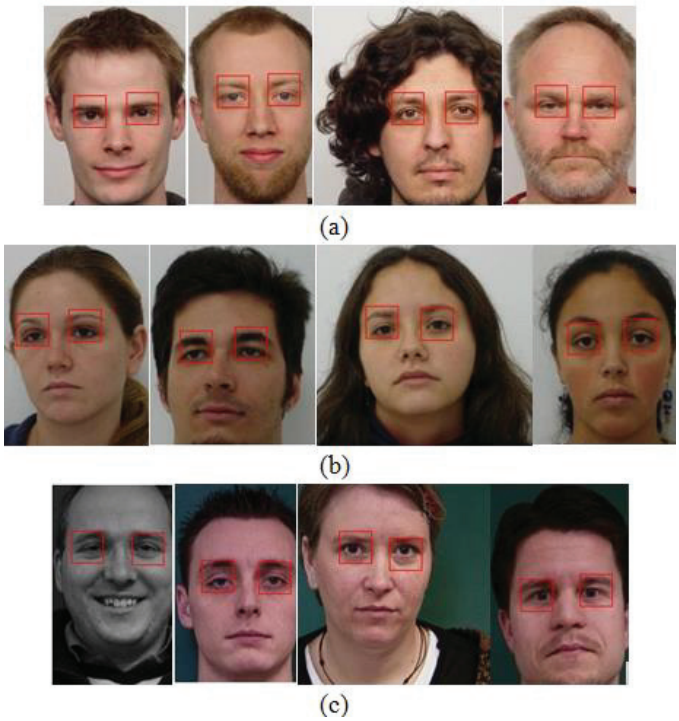


Figure 9 (a) Resultant Image of IMM frontal face image (b) Resultant Image of FEI face image (c) Resultant Image of IMM face image

V. CONCLUSION

This paper presents a method for face detection and eyes extraction using Sobel edge detection and morphological operations. The proposed method is reliable on the different images sizes of the frontal face having variation in the expressions. Except edge detection that is on gray scale image, the remaining operation is performed on binary image which reduces complexity and makes method computationally effective. It is observed from the results that algorithm of face detection for frontal face image of IMM frontal face database, FEI face database, IMM face database is successful 100%, 100%, 97% and eyes extraction result is 92.50%, 90.66%, 92.50% respectively. The work can be further improved to increase the accuracy for the eyes extraction.

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