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# Eye Detection System using Orientation Histogram

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***Abstract*— Face alignment is an important issue in face recognition systems. The performance of the face recognition system depends on the accuracy of face alignment. Since face alignment is usually conducted using eye positions, an accurate eye localization algorithm is essential for accurate face recognition. In many applications like eye-gaze tracking, iris detection for security system, the eye detection is also necessitated. In this paper, we propose a new eye detection system which can accurately detect the center of both eyes in the rotated face image. This system is composed of two portions that are face region detection and finding symmetric axis in the resulted face region to locate the position of eyes. Firstly the face region is detected and extracted from the frontal view of face image by using skin-color information in HSV. Symmetries are good candidates for describing shapes. It is a powerful concept that facilitates object detection in many situations. Thus we find the symmetric axes of the extracted face region from gradient orientation histogram of the extracted face region image by using the Fourier method and then distinguish the eyes region. Finally we find the symmetry axis of the eye to locate the center of eyes using gradient orientation histogram.**

***Index Terms*— eye detection, skin detection, symmetry detection, localization of eye.**

## I. Introduction

Human face image analysis, detection and recognition have become some of the most important research topics in the field of important research topics in the field of computer vision and pattern classification. The face recognition has many applications such as personal identification, criminal investigation, and security work and login authentication. Automatic recognition of human faces by computer has been approached in various ways. To develop the face recognition system, the analytic approach can be used to recognize a face using the geometrical measurements taken among facial features, such as eyes and mouth. In the analytic approach, reliable detection of facial features is fundamental to the success of the overall system. Thus, eyes are one of the most important facial features and eyes detection is a crucial aspect in many useful applications.

The eye position detection is important not only for face recognition but also for eye contour detection. The position of other facial features can also be estimated using the eye position to analyze the facial expression in the face. Although many eye detection methods have been developed in the last decade, a lot of problems still exist also. Factor including facial expression, face rotation in plane and depth, occlusion and lighting conditions, and all undoubtedly affect the performance of eye detection algorithms. In this paper, we propose a new algorithm for eye detection system.

The paper is organized as follows. Related work is reviewed in Section 2. In Section 3, the overall diagram of the eye detection system is presented. The algorithm of eye detection system is described in Section 4. The conclusion and future works are mentioned in Section 5.

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## II. Related Work

The existing work in eye position detection can be classified into two categories: active infrared (IR) based approaches and image-based passive approaches. Eye detection based on active remote IR illumination is a simple yet effective approach. But they all rely on an active IR light source to produce the dark or bright pupil effects. In other words, these methods can only be applied to the IR illuminated eye images. It's certain that these methods would not be widely used, because in many real applications the face images are not IR illuminated.

In this paper, we approach image-based passive method. The commonly used approaches for passive eye detection include the template matching method [1, 2], eigenspace [3] method, and Hough transform-based method [4,5].

In the template matching method, segments of an input image are compared to previously stored images, to evaluate the similarity of the counterpart using correlation values. The problem with simple template matching is that it cannot deal with eye variations in scale, expression, rotation and illumination. Use of multiscale templates was somewhat helpful in solving the previous problem in template matching. A method of using deformable templates is proposed by Yuille et al [6]. This provides the advantage of finding some extra features of an eye like its shape and size at the same time. The weaknesses of the deformable templates are that the processing time is lengthy and success relies on the initial position of the template. Lam et al. [7] introduced the concept of eye corners to improve the deformable template approach. Saber et al. [8] and Jeng et al. [9] proposed to use facial features geometrical structure to estimate the location of eyes.

Kumar et al. [10] suggest a technique in which possible eye areas are localized using a simple thresholding in color space followed by a connected component analysis to quantify spatially connected regions and further reduce the search space to determine the contending eye pair windows.

Finally the mean and variance projection functions are utilized in each eye pair window to validate the presence of the eye.

Pentland et al. [3] proposed an eigenspace method for eye and face detection. If the training database is variable with respect to appearance, orientation, and illumination, then this method provides better performance than simple template matching. But the performance of this method is closely related to the training set used and this method also requires normalized sets of training an d test images with respect to size and orientation.

Another popular eye detection method is obtained by using the Hough transform. This method is based on the shape feature of and iris and is often used for binary valley or edge maps [7, 11]. The drawback of this approach is that the performance depends on threshold values used for binary conversion of the valleys.

Various methods that have been adopted for eye detection include wavelets, principal component analysis, fuzzy logic, support vector machines, neural networks, evolutionary computation and hidden Markov models. The method proposed in this paper involves skin detection using skin color information in HSV space and eye detection using orientation histogram.

## III. OVERVIEW OF PROPOSED SYSTEM

Automatic tracking of eyes and gaze direction is an interesting topic in computer vision with its application in biometric, security, intelligent human-computer interfaces, and driver's drowsiness detection system. Eye detection is required in many applications. Localization of eyes is a necessary step for many face classification methods and further facilitates the detection of other facial landmarks.

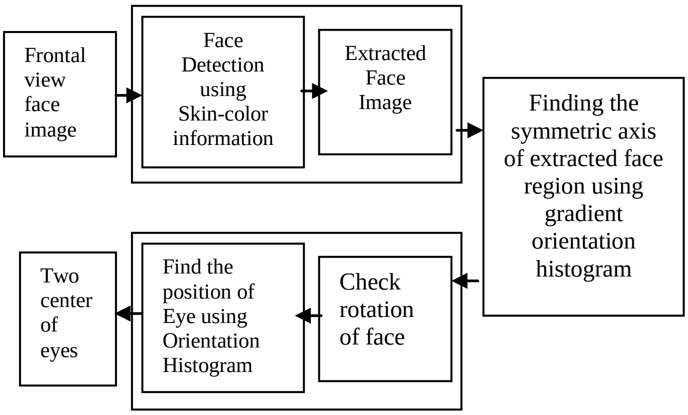


Fig. 1 Overall Diagram of Eye Detection System

In this section, we present the proposed eye detection system which consists of three portions: face region detection and extraction, finding the symmetric axis in the detected face region and defining the position of eyes using orientation histogram.

Fig.1 shows the overall diagram of proposed eye detection system. In our proposed system, the face region is firstly extracted from the image by using skin-color information in HSV space which is an efficient space for skin detection. Secondly symmetric axis of the extracted face region is searched to determine the eye in the face region by using the orientation histogram. After finding the eye shape, its symmetric axis is again searched to detect the center of eyes in the face region. The following section presents the algorithm of proposed system.

## IV. ALGORITHM OF EYE DETECTION SYSTEM

An important issue in face recognition systems is face alignment. Face alignment involves spatially scaling and rotating a face image to match with face images in the database. The face alignment has a large impact on recognition accuracy and is usually performed with the use of eye positions. In this section, the algorithms for eye detection system are presented.

### *A. Skin and Face Detection*

To detect the location of eyes, the first step we need to do is the detection of the skin region that is very important in eye detection. The skin region can help determining the approximate eye position and eliminates a large number of false eye candidates. The proposed skin detection algorithm is described as follow.

Step1. Convert the input RGB image to HSV image.

Step2. Get the edge map image from RGB image using Edge detection algorithms.

Step3.Get H & S values for each pixel and detect skin region.

Step4. Find the different regions in the image by implementing connectivity analysis using 8-connected neighbourhood.

Step5. Find height and width for each region and percentage of skin in each region.

Step6.For each region, if (height/width) or (width/height) is within the range, then the region is a face.

In the first step, the RGB input image is converted to HSV image. In the HSV space, H stands for hue component, which describes the shade of the color, S stands for saturation component, which describes how pure the hue (color) is while V stands for value component, which describes the brightness. The removal of V component takes care of varying lighting conditions. H varies from 0 to 1 on a circular scale i.e. the colors represented by H=0 and H=1 are the same. S varies from 0 to 1, 1 representing 100 percent purity of the color. H and S scales are partitioned into 100 levels and the color histogram is formed using H and S.

In the second step, we need to get the edge information in the image. There are many ways to perform edge detection. However, the most may be grouped into two categories, gradient and Laplacian. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. The Laplacian method searches for zero crossings in the second derivative of the image to find edges. Sobel, Prewitt and Roberts operators come under gradient method while Marrs-Hildreth is a Laplacian method. Among these, the Sobel operator is fast, detects edges at finest scales and has smoothing along the edge direction, which avoids noisy edges. The Sobel operator is used in edge detection. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. In simple terms, the operator calculates the gradient of the image intensity at each point, giving the direction of the largest possible increase from light to dark and the rate of change in that direction.

In the third step, we get H and S value for each pixel to detect the skin. In order to determine the skin, we need to train the skin color, get color images containing human faces and extract the skin regions in these images manually. Training set contained more than 4,50,000 skin pixels to form the color histogram in H and S. For each pixel, H and S values are found and the bin corresponding to these H and S values in the histogram is incremented by 1. After the training is completed, the histogram is normalized. Though it appears that there are two different regions very much apart with high skin probability, they both belong to the same region, since H is cyclic in nature. The skin color falls into a very small region in the entire HS space. The height of a bin in the histogram is proportional to the probability that the color represented by the bin is a skin color. So use a threshold between 0 and 1 to classify any pixel as a skin pixel or a non-skin pixel. If the threshold value is high, all the non-skin pixels will be classified correctly but some of the skin pixels will be classified as non-skin pixels. If the threshold value is low, all the skin pixels will be classified correctly whereas some of the non-skin pixels will be classified as skin pixels. This represents a trade-off between percentage of skin pixels detected as skin and percentage of non-skin pixels falsely detected as skin. There is an optimum threshold value with which one can detect most of the skin pixels and reject most of the non-skin pixels. This threshold is found by experimentation. Given an image, each pixel in the image is classified as skin or non-skin using color information. The histogram is normalized and if the height of the bin corresponding to the H and S values of a pixel exceeds a threshold called skin-threshold, then that pixel is considered a skin pixel. Otherwise the pixel is considered a non-skin pixel.

In fourth step, the detected skin image is used, one knows whether a pixel is a skin pixel or not, but cannot say anything about whether a pixel belongs to a face or not. One cannot say anything about it at the pixel level. Need to go to a higher level and so need to categorize the skin pixels into different groups so that they will represent something meaningful as a group, for example a face, a hand etc. Since have to form meaningful groups of pixels, it makes sense to group pixels that are connected to each other geometrically. Group the skin pixels in the image based on a 8-connected neighborhood i.e. if a skin pixel has got another skin pixel in any of its 8 neighboring places, then both the pixels belong to the same region.

In fifth and sixth steps, we need to classify different regions as a human face or not. This is done by finding the centroid, height and width of the region as well as the percentage of skin in the rectangular area defined by the above parameters. The centroid is found by the average of the coordinates of all the pixels in that region. For finding height:

- The y-coordinate of the centroid is subtracted from the y-coordinates of all pixels in the region.
- Find the average of all the positive y-coordinates and negative y-coordinates separately.
- Add the absolute values of both the averages and multiply by 2. This gives the average height of the region.

Average width can be found similarly by using x-coordinates. For each region, if (height/width) or (width/height) is within the range, then the region is a face.

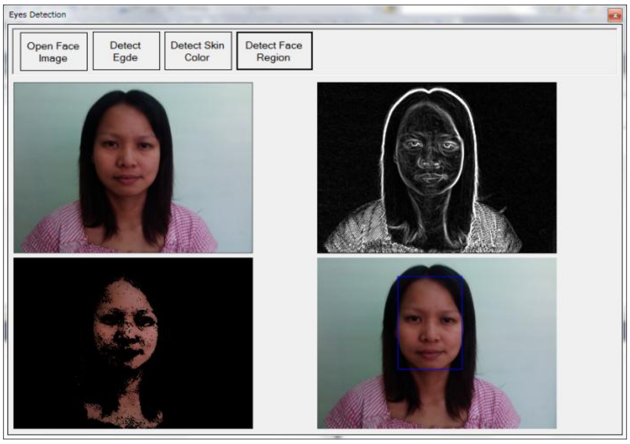


Fig. 2 Skin and Face Detection

Fig. 2 shows the step-by-step processes result of above skin and face detection algorithm. In Fig. 2, open face image button is clicked to browse the input image file. The first four steps in the above algorithm are finished by clicking the detect edge and detect skin color buttons andtheir results in these steps are exposed in this figure. The final two steps in this algorithm are done by clicking the detect face region button in figure and the result of the detected face region image is also shown in last image of Fig. 2.

*B. Symmetry Detection*

For an image described by f(x,y), the gradient vector [p,q]T at point (x,y) is defined by:

$$p = \partial f(x,y)/\partial x,\ q = \partial f(x,y)/\partial y \qquad (1)$$

The orientation of this gradient vector is:

$$\phi = \arctan(q/p) \qquad (2)$$

The gradient is obtained by using an N×N Sobel filtering operation [12]. In our experiment, we will use N=5. It splits the kernels into 2×1 sub-kernels and iteratively calculates the responses. The result is two responses for the x- and y-directions respectively. Then the gradient orientation at this point of the image can be obtained using Eq. (2). The domain of $\phi$ is $[-\pi,\pi)$. For detecting the orientation of a rotated face image, half of the range of $\phi$ will be enough. The negative values of $\phi$ are offset by $\pi$ to become positive. If we have some knowledge about the range of the rotated face angle, we can reduce the domain of $\phi$ even further.

Our algorithm is based on an observation about gradient orientation distribution of the image. For a rotated face image, there will be more points in the image whose gradient orientations are perpendicular to the line. It is expected that the statistical information of the gradient orientation of an

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image can be used for rotated angle detection. Fig. 3 gives an example shape of the gradient orientation histogram, in which θ is the rotated angle. The orientation histogram of this gradient image can be obtained as described in Eq. (2). The angle ϕ in the equation is a continuous function. Quantization is needed for the given range and resolution. The resolution of the obtained histogram depends upon the range considered and the number of points in the histogram. For instance, if we would like to have 360 points within the angle between 45˚ and 135˚, then the angle resolution will be 0.25 degree. From the obtained histogram h(ϕ), the orientation of the rotated image is the difference between angle ϕ where it gives the maximum value for h(ϕ) and π/2. For an upright image, ϕ will be π/2, hence the skew angle is zero.

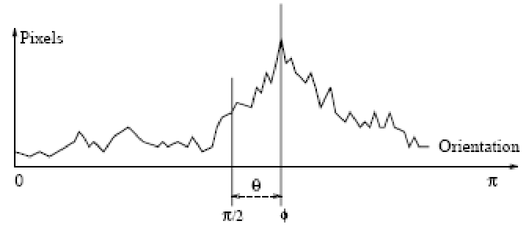


Fig. 3 An illustration for skew detection of a rotated image using gradient orientation histogram

After the angle of the rotated face has been obtained, the input image can be rotated for skew correction. During the rotation operation, bilinear interpolation of neighbouring pixels will be involved to reduce noise effect. The rotation can be realized using Eq. (3), where (cx,cy) is the center of rotation, and rij, 1≤ i, j≤ 2, are the elements of the rotation matrix.

$$\begin{bmatrix} X_{out} \\ Y_{out} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{bmatrix} \begin{bmatrix} X_{in} \\ Y_{in} \end{bmatrix} - \begin{bmatrix} c_x \\ c_y \end{bmatrix} \quad (3)$$

In this paper we use the Fourier method to obtain the symmetry information. Let h(i), i = 0, 1, …, N-1, is the sum of the discretized orientation histogram. The Fourier transform H(u) of h(i) as defined in Eq. (4) will be used to obtain the convolutions of two signals. The two signals are the same, i.e. h(i).

$$H(u) = \sum_{i=0}^{N-1} h(i)\exp\{-j2\pi iu/N\}, u = 0,1,\ldots,N-1 \quad (4)$$

The convolution of histogram h(i) can be obtained by the Fourier transform. Based on the following convolution theorem:

$$f(x)*g(x) \Leftrightarrow F(u)\times G(u \quad (5)$$

the convolution in the space domain can be obtained by taking the inverse Fourier transform of the product F(u) G(u). In our case F(u) = G(u) = H(u). Thus, we have h(i) * h(i) ⇔H2(u).

The accuracy of the orientation of the symmetry axis obtained by searching the peak positions in the convolution function can be improved by fitting a parabola function around the local region of peak.

Fig. 4 shows the example detection result of symmetry axis which will be acquired by applying the proposed symmetry detection algorithm. The proposed symmetry detection algorithm is described as follow:

Step 1: Perform a gradient operation on the detected face region image;

Step 2: Obtain the gradient orientation histogram and smoothing it with a median filter;

Step 3: Search for the convolution peaks of the gradient orientation histogram by using Fourier transform to obtain the orientations of symmetry axes;

Step 4: Search for maximum in this histogram to obtain an initial rotated angle;

Step 5: Perform the symmetry check or evaluation about the obtained symmetry axes;

Step 6: Obtain the position of this symmetry axis by using the center of mass of the object;

Step 7: Draw the symmetry axes based on the orientation and position information obtained;

Step 8: Refine the obtained initial rotated angle value by locally fitting a cubic polynomial function, and calculate the maximum analytically;

Step 9: Rotate the image for detecting the eye.

Fig. 4 Example result of symmetry detection

### C. *Eyes Center Detection*

We can obtain the eye region according to the gradient orientation histogram. Fig. 5 shows the example result of eyes centre which will be got by applying the following algorithm. The steps of the eyes extraction algorithm are described as follow:

Step 1: Perform a gradient operation on the eye image;

Step 2: Obtain the gradient orientation histogram;

Step3: Search for the convolution peaks of the gradient orientation histogram by using Fourier transform to obtain the orientations of symmetry axes;

Step 4: Perform the symmetry check or evaluation about the obtained symmetry axes;

Step 5: Draw the symmetry axes based on the orientation and position information obtained;

Step 6: Obtain the eyes center

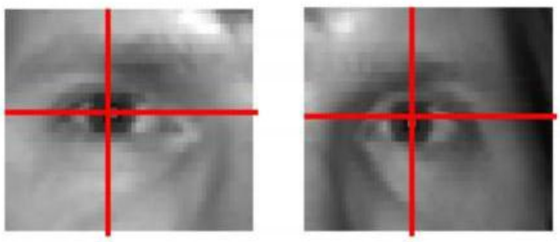

Fig.5 Example result of eyes center

## V. CONCLUSION AND FUTURE WORK

Face alignment is an important issue in face recognition systems. The performance of the face recognition system depends on the accuracy of face alignment. Since face alignment is usually conducted using eye positions, an accurate eye localization algorithm is essential for accurate face recognition. In this paper, we proposed a new eye detection algorithm that will precisely distinguish the eyes region in the rotated face image by using the skew correction method and orientation histogram. Our system will detect the center of both eyes accurately and will support to detect the center of both eyes in the scaled and additional invariant image because of the use of orientation histogram. Our future work is that we need to verify the system with various conditional images.

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