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Eye Localization using PCA Based Genetic Search

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***Abstract:** In this paper, we propose a novel approach for eye localization from human face image using GA based on PCA. As the genetic algorithm is computationally intensive, the searching space is reduced and limited to the eye regions so that the required timing is greatly reduced. Here GA is used to search for the possible eye region in an image efficiently. Specifically, we use GAs to find image sub-windows that contain the eye region. Each sub-window is evaluated using a fitness function and sub-windows containing eyes eye region is extracted. This is one of the major applications in case of retina recognition used in security purpose. The idea from the method of eigen-eye, and used to determine the fitness values.*

***Keywords:** YCbCr, Skin Region extraction, PCA, Eigen Eyes, Genetic Algorithm*

I. INTRODUCTION

Computer plays an important role in every parts of today life and society in modern civilization. With increasing technology, man becomes involved with computer as the leader of this technological age and the technological revolution has taken place all over the world based on it. It has opened a new age for humankind to enter into a new world, commonly known as the technological world. Computer vision is a part of everyday life. One of the most important goals of computer vision is to achieve visual recognition ability comparable to that of human [11].

In this paper our main objective is to detect the eyes also identify the eye of interest from a two dimensional intensity image. For that purpose we need to search the appropriate eye of interest inside the two dimensional image. And to optimize the search we have used the concept of Genetic Algorithm. So the proposed method is basically an application of Genetic Algorithm where the fitness function gives the optimum solution. The extracted eye to be identified by the help of eigen space, which can be developed using PCA and eigeneyes. M. Turk and P. Pentland developed the near real-time eigenfaces systems [2] for face recognition using eigenfaces and Euclidean distance by which one can achieve real-time recognition of faces.

Accurate eye localization is a key component of many computer vision systems [18]. Despite active research in the last twenty years, accurate eye localization in uncontrolled scenarios remains unsolved. The challenge comes from the fact that the shapes and appearances of eyes change dramatically under various pose and illumination. Glare and reflections on glasses, occlusions and eye blinks further increase the difficulty to this problem

Eye localization can be classified into three categories: geometry based approaches, appearance based approaches and context based approaches.

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The geometry based approaches model the eyes using geometric information. Yuille et al. [14] described eyes with a parameterized template consisting of circles and parabolic sections. By altering the parameter values, the template is deformed to find the best fit to the image. Bai et al. [12] applied radial symmetry transform to determine the eye centers. A recentwork of this category is Valenti et al.'s isophote Curvature method [13].

Facial feature extraction consists in localizing the most characteristic face components (eyes, nose, mouth, etc.) within images that depict human eyes. The problem of human eye detection, localization and tracking has also received significant attention during the past several years because of wide range of human- computer interaction (HCI) and surveillance applications. As eyes are one of the most important salient features of a human face, detecting and localizing them helps researchers working on face detection, face recognition, iris recognition, facial expression analysis [16], etc. Among these, eye localization is a lively research area where it has been made a great effort in the last years to design and compare different techniques.

Principal Component Analysis (PCA) is the general name for a technique which uses sophisticated underlying mathematical principles to transforms a number of possibly correlated variables into a smaller number of variables called principal components. The origins of PCA lie in multivariate data analysis; however, it has a wide range of other applications. This is based on principal component-analysis (PCA) technique, which is used to simplify a dataset into lower dimension while retaining the characteristics of dataset. Preprocessing, Principal component analysis is major implementations of this paper [11]. Pre-processing is done for two purposes i.e. one to reduce noise and possible convolute effects of interfering system and the other is to transform the image into a different space where classification may prove easier by exploitation of certain features.

The neural network based method [4] is the best one but it needs a large numbers of eye and non eye data to train the neural network, which can be eliminated in our implemented method. Here we have used PCA converts a large dimension data to a very low dimensional sub space called eigenspace [2]. Then we need to linearly project the sub-images on this space and find out the Euclidian distance from this space which determines whether it is an eye or not.

Genetic algorithm basically discovered by Goldberg [8] is mainly used for optimization purpose. A number of researches have been done over GA [2, 3, 19] for optimization in different areas of applications. In our paper we have used GA to optimize a search procedure to find out the appropriate sub-window which contains the face of interest inside the 2D scene image. So sub-windows first extracted over which GA works for certain generations to obtain the optimum solution based on a fitness function [6]. In this paper we are optimizing the search procedure and to

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reduce the search space we first extracted the skin region inside a intensity image then apply the implemented method to the skin image.

II. SKIN REGION DETECTION

The first stage in face detection is to perform skin detection. Skin detection can be performed in a number of color models. Color is a prominent feature of human skin. Using skin color as a primitive feature for detecting skin regions has several advantages. To name a few are RGB, YCbCr, HSV, YIQ, YUV, CIE, XYZ, etc. An efficient skin detection algorithm is one which should be able to cover all the skin colors like black, brown, white, etc. and should account for varying lighting conditions. Experiments were performed in RGB and YCbCr color models [5, 19] to find out the robust skin color model. The relationship between RGB and YCbCr is as follows:

$$
\begin{aligned}
Y &= 0.299R + 0.587G + 0.114B \\
Cb &= -0.169R - 0.332G + 0.500B \\
Cr &= 0.500R - 0.419G - 0.081B
\end{aligned}
\tag{1}
$$

Here in YCbCr color model, the RGB components are separated into luminance (Y), chrominance blue (Cb) and chrominance red (Cr). A skin color map is derived and used on the chrominance components of the input image to detect pixels that appear to be skin. We have here predefined a value for the chrominance level (Cr) to extract the skin region.

III. EYE DATABASE

In our proposed method we have used 50 frontal face images from 50 different individuals with different lightening condition in one database. After that we have manually cropped the eye region to create the eye database. Correspondingly a eye data base is created with 50 nos. of eyes each with size 180x50.

A. Enhancement

All eyes in the database are processing using histogram equalization. Here we are enhancing the eye features of each eye by using some enhancement technique like image gradient, for that we have used here Sobel operator using a 3×3 mask [7]. Finally the resultant image is done for thresholding with percentage of 30. Then the resultant image is now forwarded to further process of finding Eigen space.

IV. PROPOSED METHOD

The proposed method is divided into four sub-stages,
Step 1: Creation of eigen space using the database as mention above using PCA.
Step 2: Convert the input image into skin likelihood image by extracting the skin region through YCbCr color space.
Step 3: Encode sub-windows at different location and create initial population.
Step 4: Using Operators of GA and fitness function find the sub-window that contains the eye of interest.
First of all eigen space is created which works as a reference for rest of calculation. Then input image is taken from which skin region is extracted. That skin extracted image becomes the input image to Genetic algorithm. Then using GA operators different sub-windows extracted and the fitness value of all sub windows calculated. Based on best fitness values windows the outcomes will come, which will be results after some iteration.

<u>Overview of the method used:</u>

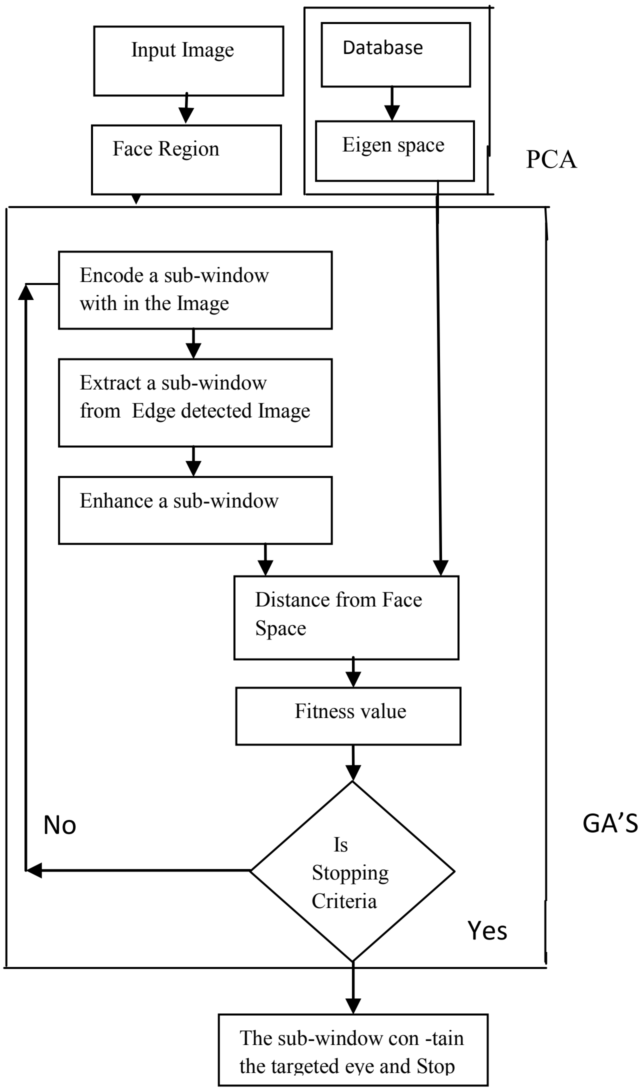

Fig.1 Flow Diagram of the proposed method

V. EIGEN EYES USING PCA

PCA is a common standard statistical technique for finding the patterns in high dimensional data's [10].Feature extraction, also called Dimensionality Reduction, is done by PCA for a three main purposes like

i) To reduce dimension of the data to more tractable limits
ii) To capture salient class-specific features of the data,
To eliminate redundancy

The method of eigen eyes is based on Principal Component Analysis (PCA), a standard statistical technique for reducing the dimensionality of data while attempting to preserve as much of information as possible in terms of variance. The main idea is to represent each data in a low dimensional space defined by the most important eigenvectors i.e., "eigeneyes"[2] of the covariance matrix of the data distribution. A complete description of the PCA approach can be found in [19]. This process is as follow:
Representing each image $I(x, y)$ as a $M \times N$ vector Γ_i, first the mean eye ψ is computed:

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$$\psi = \frac{1}{m}\sum_{i=1}^{m}\Gamma_i , \qquad (2)$$

where, m is the number of eyes in the training set.
Next, the difference ψ of each eye from the mean eye is computed : $\phi_i = \Gamma_i - \psi$. Then, the covariance matrix is estimated by:

$$C = \frac{1}{m}\sum_{i=1}^{m}\phi_i\phi_i^T = AA^T , \qquad (3)$$

where $A = [\phi_1\phi_2\phi_3.......\phi_m]$.The eigen space can then be defined by computing the eigenvectors u_i of C. Since C is very large $(M^2 \times N^2)$, computing its eigenvectors will be very expensive. Instead, we can compute v_i, the eigenvectors of $A^T A$, an $m \times m$ matrix. Then, u_i can be computed from v_i as follows:

$$u_i = \sum_{j=1}^{m} v_{ij}\phi_j , \; j = 1,2,...m . \qquad (4)$$

Usually, we only need to keep a smaller number of eigenvectors *m',* are corresponding to the K best eigen values.
Given a new image Γ, we subtract the mean (ϕ = Γ - ψ) and we compute its projection:

$$\hat{\phi} = \sum_{i=1}^{m} w_i u_i , \qquad (5)$$

where $w_i = u_i^T\phi$ are the coefficients of projection. Then compute the distance of that unknown image from eye space :

$$dist = \| \phi - \hat{\phi} \| \qquad (6)$$

This distance is called distance from eye space .

Also, an image is considered to be a eye found in the data set if the error (called the distance within eye space) between the coefficients of the eigenvectors used to represent the image and the eye in the data set is small.

VI. GENETIC SEARCH

Genetic Algorithm (GA's) are search methods based on principles of natural selection and genetics. GA's encode the decision variables of a search problem into finite-length strings referred to as chromosomes [6]. A randomly generated set of such strings forms the initial population from which the GA starts its search. Its process based on three operations selection, crossover and mutation through an objective function called fitness function.

A. Encoding

In our encoding scheme, each individual (chromosome) in the population represents a sub-window within the given input image. There are some constraints that need attention when encoding a rectangular window. First of all, to evaluate sub-windows of different size using the eigeneyes approach, we need to scale them down or up to the size of the images in the training set. Inside an image of size (H,W), a sub-window can be randomly created by four points Upper Left (UL) co-ordinates and Bottom Right (BR) co-ordinates. In the encoding process we are using binary encoding scheme where three of the four points can be represented in binary scheme.

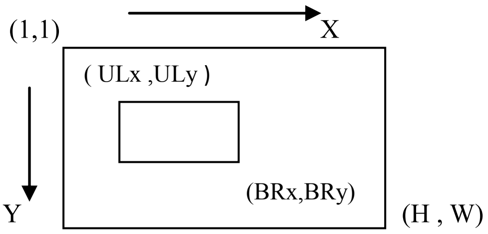

Fig.2. Schematic of Sub-window

Here the upper left point of subwindow is represented by '*m'* binary bits where $2^m \geq$ max (input image height (H), width (W)), Here we have to maintain certain constraints while encoding. The sub-window should be first resize to the size of images present in database i.e. 180x50 (MinX, MinY) using some scaling technique [7]. Then the aspect ratio of sub-window should be same as that of image in database. Each sub-window should lie within the image body.After initial population for the next generations the window can be extracted by calculating the fourth point BRx and BRy as follows:

BRx= ULx+MinX;
BRy=ULy+MinY;

The co-ordinates should be under the given inequalities

$1 \leq$ ULx $\leq$ W- MinX;
$1 \leq$ ULy $\leq$ H- MinY;

Then correspondingly BRx and BRy determine as per database image size. So the sub-windows should be fall inside the image. In further generation to decode the points we have used a linear mapping as follows:
ULx and ULy can be decoded using a linear mapping from [0, 2^m - 1] to [1, W - MinX] and from [0, 2^m - 1] to [1, H - MinY] respectively.

B. Initial Population

Initial population generated randomly. Randomly we have to generate some sets of bits streams of length L = m and decide the co-ordinate of the sub-windows using the linear mapping as given above. These sets are our initial population.

C. Fitness Function

Once the population is initialized or an offspring population is created, the fitness values of the candidate solutions are evaluated by a suitable fitness function [6]. That fitness value will decide whether it will exist for subsequent generations or not. As per our method consider we have to decide a window is fittest, if it is nearer to eye spaces, so that we can decide that it contain the eye region of target. So we have to find out here the minimum distance window is the fittest one. This nothing but the error we are calculating so we have to minimize the error but maximize the fitness value. So we have design a fitness function as:

fitness = VAL – dist ;

where VAL is very high positive value.

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D. Selection

This process chooses best copies of solutions which have the higher fitness value among the initial population. Selection is done for selection the better one and rejects the worst one. Here we have used the method of roulette-wheel selection to form a matting pool from where we have to decide the parents and generate the offspring [6].

E. Crossover

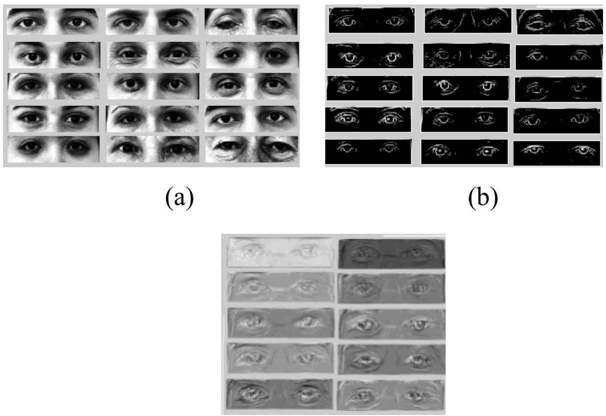
It recombines parts or more parent solution from matting pool to create new better solution called the offspring. Here we have used single point crossover by choosing a crossover point randomly and this process depends on a probability of crossover [6].

F. Mutation

This locally but randomly modifies a solution. Randomly it change one bit from the solution to have a new solution, this also depend upon a probability of mutation.

VII. EXPERIMENTAL RESULTS

We have taken FEI database [20] and manually cropped the eye region to create own database which becomes the eye database. We have considered the eye database with 50 eyes each with dimension 180x50. Then we have applied sobel operator to enhance the eye features for more accurate result. They we have perform the PCA operation to generate the eigen eye space which composed of the principle components of the eyes.



(a) (b)

(c)

Fig 3. (a) The Eye Database (b) The enhance Eyes (c) The Eigen Eyes

We have taken different frontal face image from the FEI database with different sizes. First of all we extract the skin region from the test images. Then the skin likelihood image is searched by genetic search we drastically reduces the search operation.

Fig.4 Skin Region Extraction

After extraction of extraction then resultant image is populated by image and we find the fittest window after first generation. The consequently after 50 generation we find the resultant image with localized eye. Then the best fitness value in subsequent generation is plotted.

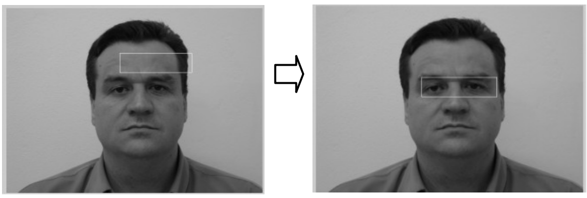


Fig. 5 The image after initial population and after applying GA

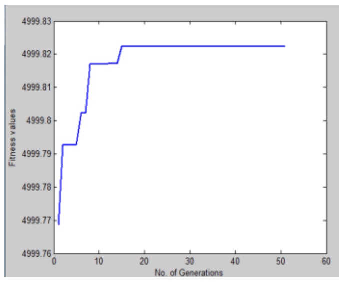


Fig. 6 The performance Plot.

We have shown some of the result and the performance plot for different size of test images as below.

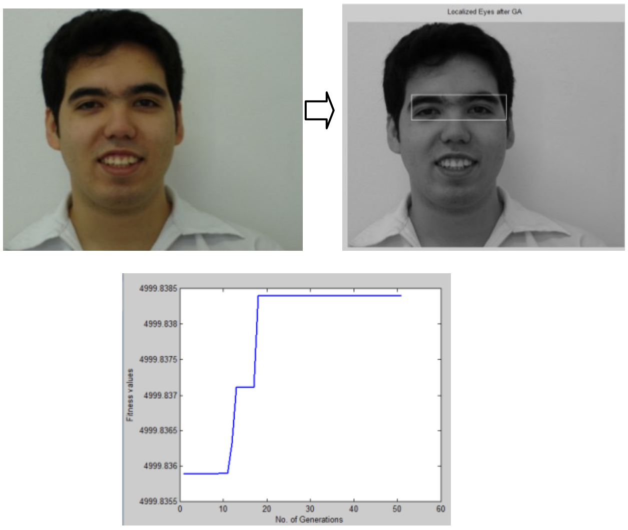


Fig. 6 Image Size (526 x 450), Localized eye and Performance Plot

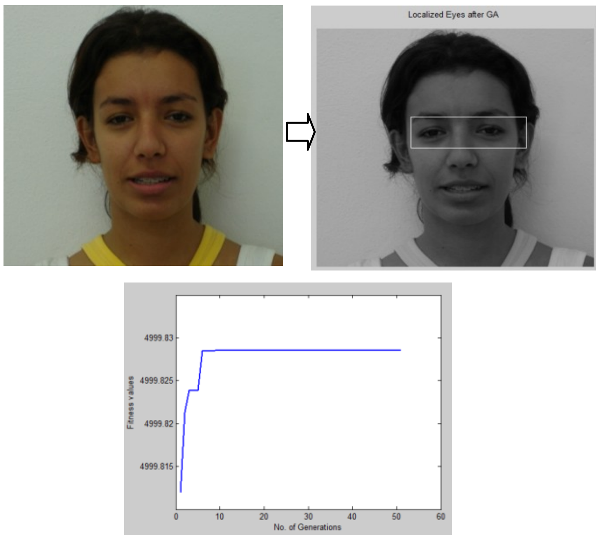


Fig. 6 Image Size (433 x 384), Localized eye and performance plot

After experiment with around 50 test image we have compared the ordinary search and genetic search for each image. Some result shown below:

Sl No	Image Size	Ordinary Search	Genetic Search
1	640x480	307200	750
2	530x425	225250	500
3	526x450	236700	900
4	433x384	181632	450
5	519x433	224727	500

Table 1. Comparison between genetic search and ordinary search

VIII. CONCLUSION

In this paper we are searching for the eyes and due to large search space we are optimizing the search procedure. For that we have used here the method of genetic algorithm which is a prominent and efficient tool for optimization. The extraction and localization of eyes, we have used the method of eigen eyes where identification has been done on the basis of Euclidean distance from eye space, with the method of PCA. The Principal Component Analysis (PCA) is the efficient way to reduce the dimension and mathematical complexity. The input color image has not applied for the method directly rather we have first extracted the skin region and made the image as a skin likelihood image. This is done for quicker convergence in Genetic Algorithm. The solution is based on a fitness function which designed by calculating distance from eye space.
So in future, we have aimed to apply it on multiple faces.

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