MAJOR PROJECT REPORT

ON

A NOVEL FUZZY EYE PAIR DETECTION ALGORITHM WITH APPLICATION TO FACE RECOGNITION

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CERTIFICATE

This is to certify that the work contained in the thesis titled *“**A novel Fuzzy Eye Pair Detection Algorithm with application to Face Recognition**”* is an original piece of work which has been carried out by **Pooja Kadyan** (08/ISY/2K10) for the award of the degree of ***Master of Technology in Information System*** (Department of Information Technology) under my supervision. This work has not been submitted elsewhere for any degree.

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ABSTRACT

Eye detection is a crucial step in a variety of applications ranging from human computer interface, driver behaviour analysis, face recognition systems and compression techniques. The localization of eyes is thus important to accurately perform these tasks. Wide range of research is done in this field over the last decade. In the field of computer vision it mainly focuses on the task of identifying or locating eye pair in an image. The proposed work is based on fuzzy classification for detection of the actual eye pair. The fuzzy Eye Detection Algorithm basically uses eight geometrical facial features and their Gaussian memberships for detecting the eye pairs. After detecting the eye pair, the distance between the eyes is used for normalizing and cropping the face image. We use Utrecht database for our work. The results illustrate the efficiency of the proposed method. Performance of the proposed method has been compared against neural network and Eye Variance Filter given by feng [25]. With our proposed approach we are able to obtain 96.36% result. .It can be seen that our proposed system gives highest performance in comparison to other methods. The proposed method is has a major application in the face recognition system. We have used PCA as the feature extraction method and the Nearest Neighbour Classifier for the classification of images. It is seen that the recognition rate for 10 random images by the application of proposed method is 100% while it is 80% without using the proposed method.

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CHAPTER 1

INTRODUCTION

1.1 Biometrics

1.1.1 History of biometrics

The term "biometrics" is derived from the Greek words bio (life) and metric (to measure).

Biometrics is becoming an interesting topic now in regards to computer and network security, however the ideas of biometrics have been around for many years. Possibly the first known example of biometrics in practice was a form of finger printing being used in China in the 14th century, as reported by explorer Joao de Barros. He wrote that the Chinese merchants were stamping children's palm prints and footprints on paper with ink to distinguish the young children from one another. This is one of the earliest known cases of biometrics in use and is still being used today.

In the 1890s, an anthropologist named Alphonse Bertillion sought to fix the problem of identifying convicted criminals and turned biometrics into a distinct field of study. He developed 'Bertillonage', a method of bodily measurement which got named after him. The problem with identifying repeated offenders was that the criminals often gave different aliases each time they were arrested. Bertillion realized that even if names changed, even if a person cut his hair or put on weight, certain elements of the body remained fixed, such as the size of the skull or the length of their fingers. His system was used by police authorities throughout the world, until it quickly faded when it was discovered that some people shared the same measurements and based on the measurements alone, two people could get treated as one.

After this, the police used finger printing, which was developed by Richard Edward Henry of Scotland Yard, instead. Essentially reverting to the same methods used by the Chinese for years. However the idea of biometrics as a field of study with useful identification applications was there and interest in it has grown. Today we have the technology to realise the aims, and to refine the accuracy of biometric identification, and therefore the possibility of making it a viable field.

What is biometrics?

Biometric recognition, or biometrics, refers to the automatic identification of a person based on his/her anatomical (e.g., fingerprint, iris) or behavioral (e.g., signature) characteristics or traits. This method of identification offers several advantages over traditional methods involving ID cards (tokens) or PIN numbers (passwords) for various reasons: (i) the person to be identified is required to be physically present at the point-of-identification; (ii) identification based on biometric techniques obviates the need to remember a password or carry a token. With the increased integration of computers and Internet into our everyday lives, it is necessary to protect sensitive and personal data. By replacing PINs (or using biometrics in addition to PINs), biometric techniques can potentially prevent unauthorized access to ATMs, cellular phones, laptops, and computer networks. Unlike biometric traits, PINs or passwords may be forgotten, and credentials like passports and driver's licenses may be forged, stolen, or lost. As a result, biometric systems are being deployed to enhance security and reduce financial fraud. Various biometric traits are being used for real-time recognition, the most popular being face, iris and fingerprint. However, there are biometric systems that are based on retinal scan, voice, signature and hand geometry. In some applications, more than one biometric trait is used to attain higher security and to handle *failure to enroll* situations for some users. Such systems are called multimodal biometric systems.

A *biometric system* is essentially a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the acquired data, and comparing this feature set against the template set in the database.

"Biometrics is the development of statistical and mathematical methods applicable to data analysis problems in the biological sciences"

A biometric system based on physiological characteristics is generally more reliable than one which adopts behavioural characteristics, even if the latter may be more easy to integrate within certain specific applications. Depending on the application context, a biometric system may operate either in *verification* mode or *identification* mode.

- **Verification** – A one-to-one comparison (1:1) of a biometric for a person for whom you wish to verify.

- **Identification** – A one-to-many comparison (1:N) of a biometric against a biometric database in attempt to identify an unknown individual.

Verification equates to *Am I who I claim I am?* When you enrol a customer for the first time, you also capture additional information such as name, phone number, or social security number. When the customer returns, they are identified through one of those pieces of information, then *verified* through the biometric match. Verification only proves that the person in front of you now is the one who originally enrolled.

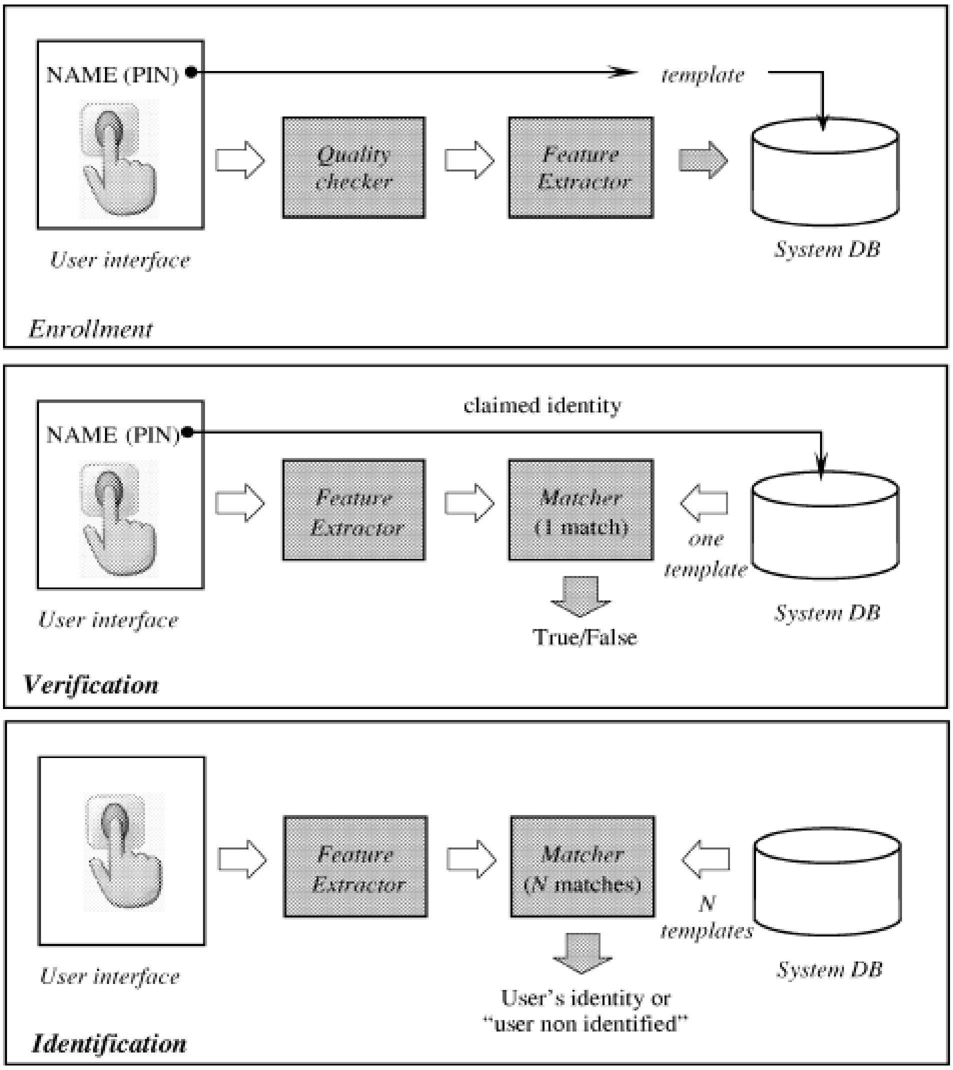


Fig. 1.1: Block diagrams of enrolment, verification, and identification tasks are shown using the four main modules of a biometric system, i.e., sensor, feature extraction, matcher, and system database.

Identification on the other hand, answers the question "*Who am I?"* A customer is enrolled with fingerprint and additional information as noted in verification. The customer can then be identified from only their fingerprint because the system compares that fingerprint against an entire database (hence the expression one-to-many). This allows for prevention of enrolments with near-duplicate information or multiple IDs.

What biological measurements qualify to be a biometric?

Any human physiological and/or behavioral characteristic can be used as a biometric characteristic as long as it satisfies the following requirements:

- *Universality*: each person should have the characteristic.
- *Distinctiveness*: any two persons should be sufficiently different in terms of the characteristic.
- *Permanence*: the characteristic should be sufficiently invariant (with respect to the matching criterion) over a period of time.
- *Collectability*: the characteristic can be measured quantitatively. However, in a practical biometric system (i.e., a system that employs biometrics for personal recognition), there are a number of other issues that should be considered, including:
- *performance*, which refers to the achievable recognition accuracy and speed, the resources required to achieve the desired recognition accuracy and speed, as well as the operational and environmental factors that affect the accuracy and speed;
- *Acceptability*, which indicates the extent to which people are willing to accept the use of a particular biometric identifier (characteristic) in their daily lives;
- *Circumvention*, which reflects how easily the system can be fooled using fraudulent methods.

1.1.2 Biometric system components:

A simple biometric system consists of four basic components as shown in Fig. 1.2:

1) *Sensor module* which acquires the biometric data;

2) *Feature extraction module* where the acquired data is processed to extract feature vectors;

3) *Matching module* where feature vectors are compared against those in the template;

4) *Decision-making module* in which the user's identity is established or a claimed identity is accepted or rejected.

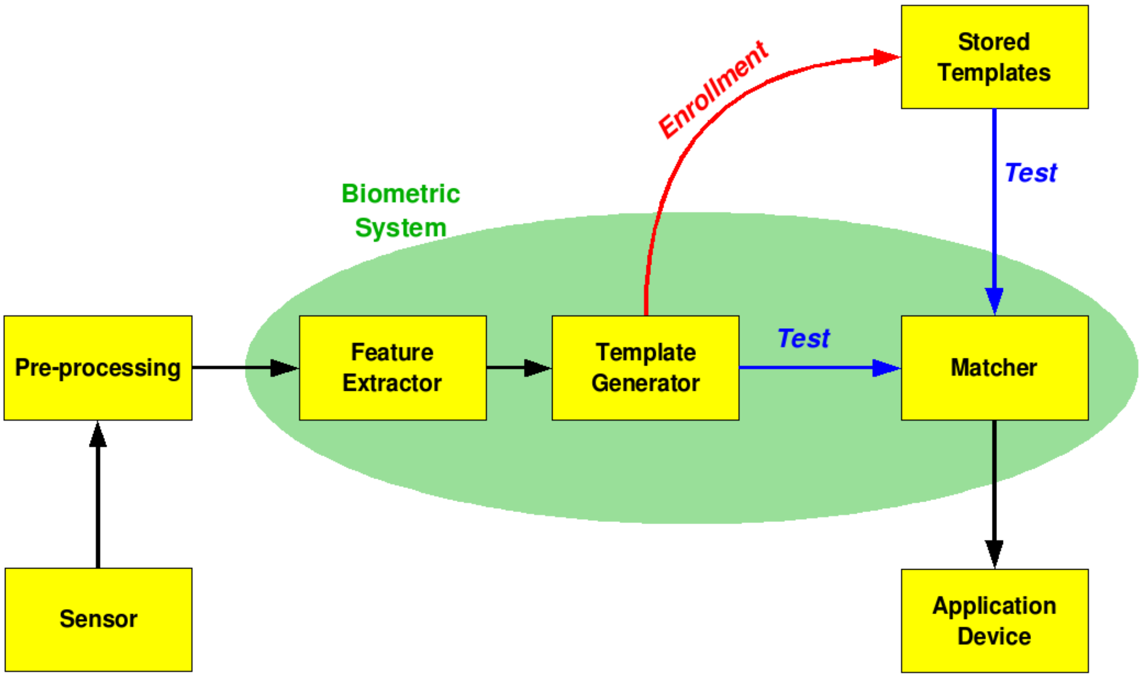


Fig.1.2 Biometric System Architecture

Performance of biometrics:

The following are used as performance metrics for biometric systems shown in Fig 1.3:

- *False accept rate or false match rate (FAR or FMR):* the probability that the system incorrectly matches the input pattern to a non-matching template in the database. It measures the percent of invalid inputs which are incorrectly accepted. In case of similarity scale, if the person is imposter in real, but the matching score is higher than the threshold, and then he is treated as genuine that increases the FAR and hence performance also depends upon the selection of threshold value.

- *False reject rate or false non-match rate (FRR or FNMR):* the probability that the system fails to detect a match between the input pattern and a matching template in the database. It measures the percent of valid inputs which are incorrectly rejected.

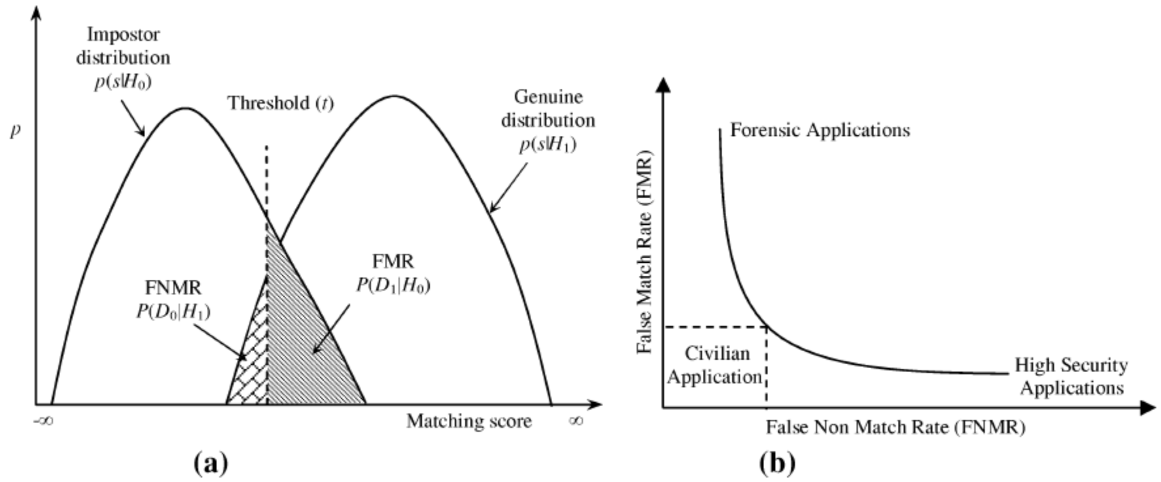


Fig. 1.3 (a): Biometric system error rates. FMR and FNMR for a given threshold t are displayed over the genuine and impostor score distributions; FMR is the percentage of nonmate pairs whose matching scores are greater than or equal to t, and FNMR is the percentage of mate pairs whose matching scores are less than t. **(b):** Choosing different operating points results in different FMR and FNMR. The curve relating FMR to FNMR at different thresholds is referred to as receiver operating characteristics (ROC). Typical operating points of different biometric applications are displayed on an ROC curve. Lack of understanding of the error rates is a primary source of confusion in assessing system accuracy in vendor/user communities alike.

- *Receiver operating characteristic or relative operating characteristic (ROC):* The ROC plot is a visual characterization of the trade-off between the FAR and the FRR. In general, the matching algorithm performs a decision based on a threshold which determines how close to a template the input needs to be for it to be considered a match. If the threshold is reduced, there will be fewer false non-matches but more false accepts. Correspondingly, a higher threshold will reduce the FAR but increase the FRR. A common variation is the *Detection error trade-off (DET),* which is obtained using normal deviate scales on both axes. This more linear graph illuminates the differences for higher performances (rarer errors).

- *Equal error rate or crossover error rate (EER or CER):* The rate at which both accept and reject errors are equal. The value of the EER can be easily obtained from the ROC curve. The EER is a quick way to compare the accuracy of devices with different ROC curves. In general, the device with the lowest EER is most accurate.

- *Failure to enrol rate (FTE or FER):* the rate at which attempts to create a template from an input is unsuccessful. This is most commonly caused by low quality inputs.

- *Failure to capture rate (FTC*): Within automatic systems, the probability that the system fails to detect a biometric input when presented correctly.

- *Template capacity:* the maximum number of sets of data which can be stored in the system.

A number of biometric characteristics exist and are in use in various applications (see Fig 1.4). Each biometric has its strengths and weaknesses, and the choice depends on the application. No single biometric is expected to effectively meet the requirements of all the applications. In other words, no biometric is "optimal." The match between a specific biometric and an application is determined depending upon the operational mode of the application and the properties of the biometric characteristic. Some of the commonly used biometrics are shown in the fig 1.4 shown below:

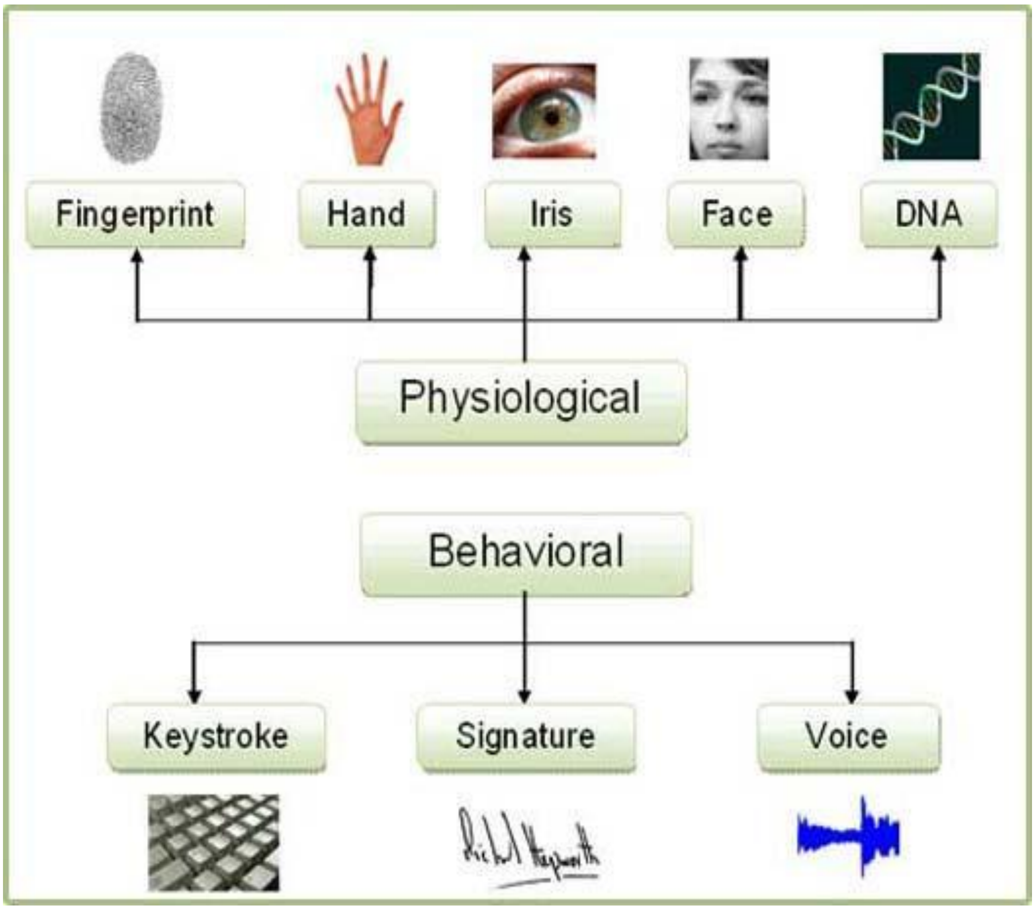


Fig. 1.4 Types of Biometrics

1.1.3 Eye detection:

Eye detection is a crucial step in a variety of applications ranging from human computer interface, driver behaviour analysis, face recognition systems and compression techniques. The localization of eyes is thus important for accurate face recognition tasks

Wide range of research is done in this field over the last decade. A typical face recognition system consists of face detection, alignment and recognition. It has been shown that face alignment is very important for a face recognition system [1]. In general, face is aligned by eye locations. Therefore a fast and accurate eye detector is crucial for a face recognition system.

Many face recognition systems are based on facial features, such as eyes, nose and mouth, and their spatial relationship, called the constituted approach [1, 2]. Eyes are the most important facial features. So the detection of eyes will be the first step in a recognition system. In the face-based approach, eye corners are important [1, 3]. In this approach, faces have to be aligned before recognition. Moreover, eye corners are also the important landmarks in the face [4]. Many statistical-based face recognition systems, such as eigenface [3] or independent component analysis method [5] use eye corners for alignment. A brief review on existing eye detection methods is given in Section 2. Many eye detection methods have been developed in the last decade. The existing methods can be divided into two categories.

The first category assumes that rough eye regions (which we called eye windows) have been located or there are some restrictions on the face image such that eye windows can be easily located. The detection of eyes in the face is then operated on the eye windows. Basically, if the eye windows can be located, the results are generally good. However, in practice, the eye windows cannot be easily detected.

The second category started from a cluttered image. A face detection algorithm [6,7] is adopted to locate faces in images. Eye detection is then proceeded based on the detected face(s). As the face detection algorithms are mature, it is reasonable to adopt an existing algorithm for face detection. However, there are two problems. The first problem is that a face detection algorithm usually gives a rough estimation of face region. The accuracy in locating eye windows will be highly sensitive to (1) how accurately the face can be detected and (2) the hairstyle of the person. This problem can be partially solved by using skin color information [8]. However, in many situations, such as image captured at night, color information cannot be obtained. Generally the detection of eyes is done in two steps: locating face to extract eye regions and then eye detection from eye window. The face detection problem has been faced up with different approaches: neural network, principal components, independent components, and skin color based methods.

Recently, methods based on boosting have become the focus of active research. The eye detection is done in the face regions which have been already located [38], [39], [40].

Little research has been done, however, on the direct search for eyes in whole images. Some approaches are based on active techniques: they exploit the spectral properties of pupil under near IR illumination. For example, in [41] two near infrared multiple light sources synchronized with the camera frame rate have been used to generate bright and dark pupil images. Pupils can be detected by using a simple threshold on the difference between the dark and the bright pupil images. In [42], iris geometrical information is used for determining a region candidate that contains an eye in the whole image, and then the symmetry is used for selecting the pair of eyes. Although the detection rate is high, the assumption that the distance between the camera and the person does not change greatly limits its practical applicability.

1.1.4 Classification of Eye Detection methods

Localization and extraction of eyes are operations requisite for solving problem. Eye detection can be classified into two categories: passive and active. Active approach is to detect eyes by using infrared source to create a “red-eye effect”. Passive approach can be further classified into different categories [4] [1] :

(1) Shape-based Approaches which described by its shape. Shape-based techniques utilise circular and elliptical shapes and curvatures in the eye region to locate the eye-lids, iris and pupil [5, 6]. These methods are usually quite precise, but they fail to detect eyes that are not wide open. The open eye is well described by its shape, which includes the iris and pupil contours and the exterior shape of the eye (eyelids). Categorization of shape-based approaches depends on whether the prior model is simple elliptical or of a more complex nature. Shape models usually constitute two components: a geometric eye model and a similarity measure. The parameters of the geometric model define the allowable template deformations and contain parameters for rigid (similarity) transformations and parameters for nonrigid template deformations. Deformable shape models often rely on a generic deformable template by which the eye is located by deforming the shape model through an energy minimization. An important property of these methods is their general ability to handle shape, scale, and rotation changes.

(2) Feature-Based Shape Methods which explore the characteristics of the human eye to identify a set of distinctive features around the eyes. The limbus, pupil (dark-bright pupil images) and cornea reflections are common features used for eye localization. These methods analyse local image features that are specific to the eye region. They are usually extracted using morphology-based techniques [14, 7] or filter responses [8]. Compared to the holistic approaches, feature-based methods aim to identify informative local features of the eye and face that are less sensitive to variations in illumination and viewpoint.

- Local Features by Intensity

The eye region contains several boundaries that may be detected by gray-level differences. Herpers et al. [61] propose a method that detects local features, such as edges and lines, their orientation, lengths, and scale, and use a prior eye shape model to direct local contour following. The method initially locates a particular edge and then uses steerable Gabor filters to track the edge of the iris or the corners of the eyes. Based on the eye model and the features, a sequential search strategy is initiated in order to locate the eye position, shape, and corners.

- Local Feature by Filter Responses

Filter responses enhance particular characteristics in the image while suppressing others. A filter bank may therefore enhance desired features of the image and, if appropriately defined, deemphasize irrelevant features. The value of the pixels in the image after filtering is related to the similarity of the region to the filter. Regions in the image with particular characteristics can therefore be extracted through the similarity value. Sirohey et al. [63], [64] present methods for eye detection using linear and nonlinear filtering and face modelling. Edges of the eye's sclera are detected with four Gabor wavelets. A nonlinear filter is constructed to detect the left and right eye corner candidates. The eye corners are used to determine eye regions for further analysis. Post-processing steps are employed to eliminate the spurious eye corner candidates.

- Pupil Detection

When the eye is viewed sufficiently closely, the pupil is a common and fairly reliable feature for eye detection. The pupil and iris may be darker than their surroundings and thresholds may be applied if the contrast is sufficiently large. Yang et al. and Stiefelhagen et al. [69], [65], [66] introduce an iterative threshold algorithm to locate the pupils by looking for two dark regions that satisfy certain anthropometric constraints using a skin-color model. Their method is limited by the results of the skin-color model and it will fail in the presence of other dark regions such as eyebrows and shadows. Even applying the same thresholds for both eyes seems likely to fail, especially considering different face orientations or different light conditions. Simple darkest pixel finding in search-windows centered around the last found eye positions is used for tracking. This scheme fails when there are other regions with similar intensity or during eye closure. Dark region detection may be more appropriate when using IR light than when using visible light

(3) **Appearance- Based Methods:** While the shape of the eye is an important descriptor, so is its appearance. The appearance-based methods are also known as image template or holistic methods. The appearance-based methods detect and track eyes directly, based on the photometric appearance as characterized by the color distribution or filter responses of the eye and its surroundings. These methods are independent of the actual object of interest and are, in principle, capable of modelling other objects besides eyes. The term appearance may be understood as one or several images (templates) defined point-wise with appearance given by the changes of intensity or their filter responses. The appearance-based approaches are carried out either in the spatial or in a transformed domain. One of the main benefits of performing eye detection (object detection in general) in a transformed domain is to alleviate the effect of illumination variation by preserving subbands that are less sensitive to illumination and removing bands that are sensitive to illumination change. Such techniques, however, are in practice only tolerant to moderate illumination change. Appearance-based methods can be image template based, where both the spatial and intensity information of each pixel are preserved and holistic in approach, where the intensity distribution is

characterized by ignoring the spatial information. Image template-based methods have inherent problems with scale and rotational changes. In addition, single-template models are limited by not modelling inter-person variations. Even changes in head pose and eye movements within the same person can negatively influence them. Appearance based methods operate using an eye template defined either in the intensity domain [9] or using subspace methods [10]. Among the appearance-based methods, Viola– Jones object detector is also successfully used for eye detection [11,12]. These detectors are heavily dependent on training, during which a cascade of simple Haar features-based classifiers is generated [13] .Li et al. choose 5% of the darkest pixels as eye candidates in a pre-defined eye window and then locate eyes through histogram projection [18]. However this algorithm cannot effectively differentiate hair, eyebrow and dark shadows from eyes. Lin and Yang detect eyes by Dark Pixel Filter [15]. They firstly detect a face circle and then search for eyes in the upper half of the face circle. However they only consider vertical pixel differences and ignore neighbouring pixels in other directions. Chen and Kubo locate eyeballs by combining logical product of responses of four Gabor Filters at 0, 45, 90 and 135 degrees in a pre-defined eye window [16]. Chan et al. also use the Gabor filter to detect the horizontal line lying along two eyes and use Angular Radial Transform to detect dark eyeball [17]. The combination of output of those two transforms gives the eye locations. Intensive calculation is needed for Chen and Kubo's algorithm and Chan et al.'s algorithm because of Gabor filter applied.

(4) Hybrid Models which aim at combining the advantages of different eye-models within a single system to overcome their respective shortcomings.

- Based on Shape and Intensity

The combination of shape and appearance can, for example, be achieved through part-based methods. Part-based models attempt to build a general model by using a shape model for the location of particular image patches. In this way, a model of the individual part variances can be modelled explicitly while the appearance is modelled implicitly. Xie et al. [67], [68] suggest a part-based model employing a prior shape model consisting of several subcomponents. The eye region is initially detected through thresholding and binary search and is then divided into several parts: the whole eye region, two regions representing the sclera, the whole iris, and the occluded and unoccluded portions of the iris. The irises and the eyelids are modelled by circles and parabolas that have predetermined parameters and intensity distribution. Other methods combine shape and appearance models more explicitly. Ishikawa et al. [62] and Witzner et al. [60] propose methods that combine shape and appearance models through an Active Appearance Model (AAM) [58]. In these models, both shape and appearance are combined into one generative model. The model can then be fitted to the image by changing the parameters according to a learned deformation model. Fig. 4 shows generated eyes along the first principal directions of the model [59].

(5) Other Methods which employing temporal information and active light. In [19], skin-color filter is used to extract face. The eye position is gained by gradient characteristic projection and corresponding conditions setting. In [20] use the Haar-like features to detect the eye. This method trains classifiers with a few thousands of sample view images of object and construct a cascade of classifiers to detect eye rapidly.

1.2 Review on existing methods

Eye detection mainly consists of localization of face and further detection of eyes in that face. Some of the methods are discussed below.

In 1998, Sung and Piggio [22] developed an example-based approach for locating vertical frontal views of human face in complex scenes. The approach they used was to model the distribution of human face by means of `face and `non-face images. However there was a major drawback with this algorithm. This method failed to detect faces with different orientations as it was developed for vertical frontal view faces.

Lam and Yan [2] and Yuen et al. [25] developed a snake model for detecting face boundary. Further based on the anthropological human model [24] ,they located the eye windows. But the snake model can only give good results in boundary detection if the initial position is close to the target. A neural network based upright frontal face detection system was developed by Rowley et al.[21] in which a connected neural network is employed to examine small windows of an image and decide whether each window contains a face or not. This method is further developed [26] to detect faces with different orientations. Moghaddam and Pentland [27] presented an approach to use principal component analysis to describe the face pattern with lower-dimensional feature space.

Matsuno et al. [28] proposed a method to precisely locate the face by horizontal and vertical projections i.e. to form a potential net to detect human face. Jeng et al. [29] adopted an approach to remove the effect of complex background by using morphological operations and boost filtering. A run length local table method is used to find the maximum connected blocks and further the center and orientation of the block is determined by moment. These connected blocks will be the eye windows and for the correctness of eye window localization a grouping algorithm is used.

The methods discussed in the previous paragraph work on gray scale images. Saber and Tekalp [23] performed face detection on the basis of skin color characteristics. Is used the shape symmetry is used to find whether it is a correct face region or not. Again, they focused on the frontal view face images. Also, Sobettka et al. [30] showed that human skin color for all races is clustered in normalized RGB space.

The red eye effect based eye detector is very robust and fast [33, 34]. However, there are three issues with this proposed scheme: 1) there is the need of specialized hardware, e.g. IBM PupilCam; 2) it is only applicable to videos; 3) the video needs to be taken at a short distance from the face in order to get the reflection from the pupils. Hsu, Mottaleb and Jain proposed an illumination-based eye detection method [31]. Although their method is reasonably robust, it is computationally expensive and it only works for colour images. Chiang, Tai, Yang, Huang and Huang proposed an eye detector based on the darkest part of the face [35]. In their method, the colour image is converted to equalized grey-level histogram. A threshold is applied to identify the eyes. Although this method is relatively fast, it fails to work with images of people with dark skin because their eyes are not always the darkest parts of their faces. Kumar, Raja and Ramakrishnan proposed a eye detection method [37] based on colour and projection functions, which is similar to [35]. Kawaguchi, Rizon and Hidaka proposed an eye detector that is based on Hough transform and separability filter [36]. The problem with this method is that it requires the rough size of the pupil to be known. Also, due to circle fitting in Hough transform, it is computationally expensive.

Various other algorithms have been proposed for eye detection. Huchuan Lu [43] proposed an algorithm of eye detection based on rectangle features and pixel texture features. Firstly

Adaboost classifier constructed by the rectangle features is used to detect the eyes initially. Then the size of result image is adjusted and the pixel texture features are computed. Finally the pixel texture features are input into Adaboost and SVM classifier to exactly get the location of the eyes. However, a mass of samples is used for training classifier in the algorithm, while the increased extracting and computing of features for improving the accuracy increased the calculation amount. M.W.K Wan Mohd Khairosfaizal [44] detected eyes using the Circle Hough transform. The Hough transform is applied to detecting the circle of eyes and then the eye pair is marked. But the Hough transform takes great calculation amount and some complexes pro-processing are prior to do before the transform in the method. Wang Jian [45] detected eye using an algorithm combining area-blocks pairing and multi-angle template matching. The face region is extracted by skin model, and then eyes area-blocks are obtained by morphological operation. The algorithm based on area blocks pairing and multi-angle template matching exactly located eyes finally. The deficiency of the algorithm is that both the area-blocks pairing one by one and the template matching itself increased calculation amount and time complexity, so the real-time of the algorithm is restricted. Z. Zhou and X. GengZ [46] defined a generalized projection function (GPF), which combining integral projection function (IPF) and hybrid projection function (HPF). The projection is applied to locating eye. The directly application of this algorithm made the calculation simply but it is easily disturbed by external condition such as light condition, etc. Jianfeng Ren [47] proposed an eye detection algorithm based on rank order filter. Circle mask and rank order filter are applied in detection eye candidates and then geometric constraints are used to locate eyes exactly. The difference between the circle mask and eye, and some geometric constraints application in excluding the no eye candidates affect the time efficiency and accuracy of the algorithm to some extent.

1.3 Thesis Outline

The organization of this thesis is as follows. Chapter 2 describes Eye detection literature work as well as the proposed work. This chapter gives detailed description of the work proposed i.e. the facial features, the memberships we have used and the decision making on the basis of memberships. Chapter 3 discusses review of various comparison methods i.e. Neural Networks and the eye variance filter. Chapter 4 discusses the results of the proposed method. Chapter 5 presents application of the proposed method to the face recognition system by using PCA as feature extraction method. Lastly in Chapter 6 the concluding remarks and future work are stated.

CHAPTER-2

PROPOSED FUZZY EYE PAIR DETECTION ALGORITHM

2.1 A review of Fuzzy Logic

- Fuzzy, or multi-valued logic, was introduced in the 1930s by Jan Lukasiewicz, a Polish philosopher. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to all real numbers in the interval between 0 and 1.For example, the possibility that a man 181 cm tall is really tall might be set to a value of 0.86. It is likely that the man is tall. This work led to an inexact reasoning technique often called possibility theory.
- In 1965 Lotfi Zadeh, published his famous paper "Fuzzy sets" [49]. Zadeh extended the work on possibility theory into a formal system of mathematical logic, and introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called fuzzy logic.

Why fuzzy?

As Zadeh said, the term is concrete, immediate and descriptive; we all know what it means. However, many people in the West were repelled by the word fuzzy, because it is usually used in a negative sense.

Why logic?

Fuzziness rests on fuzzy set theory, and fuzzy logic is just a small part of that theory.

Fuzzy logic uses the whole interval between 0 (false) and 1 (true) to describe human reasoning. In fuzzy sets, the smooth transition is characterized by membership functions that give fuzzy set flexibility. A fuzzy set is any set that allows its members to have different degree of membership, called membership function, in the interval [0, 1]. Membership function maps each element of a set to a membership grade between 0 and 1 to express the degree to which the element belongs to the set.

Fuzzy systems are very useful in two general contexts:

1. In situations involving highly complex systems whose behaviors are not well understood.
2. In situations where an approximate, but fast, solution is warranted.

2.1.1 Membership functions:

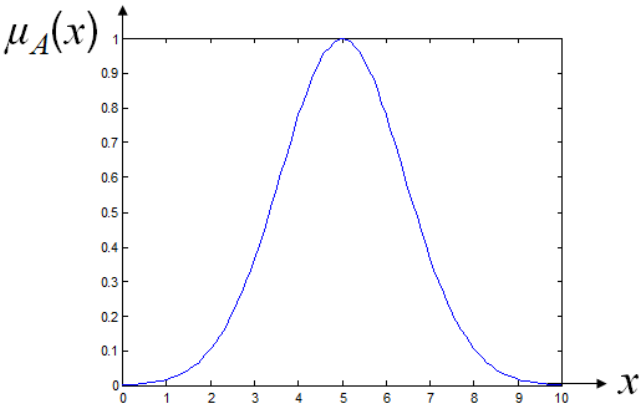
The membership function of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. For any set X, a membership function on X is any function from X to the real unit interval [0, 1]. The membership function which represents a fuzzy set $\tilde{A}$ is usually denoted by μ_A For an element x of X, the value μ_A (x) is called the membership degree of x in the fuzzy set $\tilde{A}$. The membership degree μ_A (x) quantifies the grade of membership of the element x to the fuzzy set $\tilde{A}$. The value 0 means that x is not a member of the fuzzy set; the value 1 means that x is fully a member of the fuzzy set. The values between 0 and 1 characterize fuzzy members, which belong to the fuzzy set only partially.

There are different shapes of membership functions [50]; triangular, trapezoidal, piecewise-linear, Gaussian, bell-shaped, etc. Gaussian membership function is discussed below:

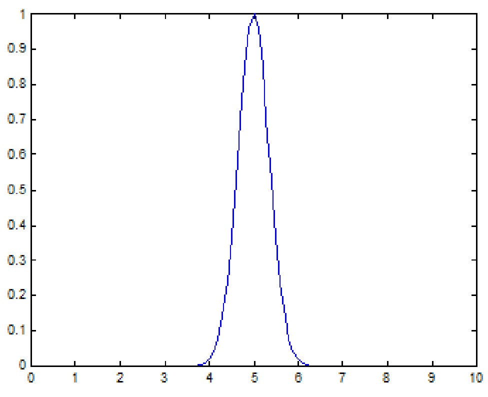
2.1.2 Gaussian membership function: The Gaussian curve is given by

$$\mu_A(x,c,s,m) = \exp\left[-\frac{1}{2}\left|\frac{x-c}{s}\right|^m\right] \qquad \textbf{.... (2.1)}$$

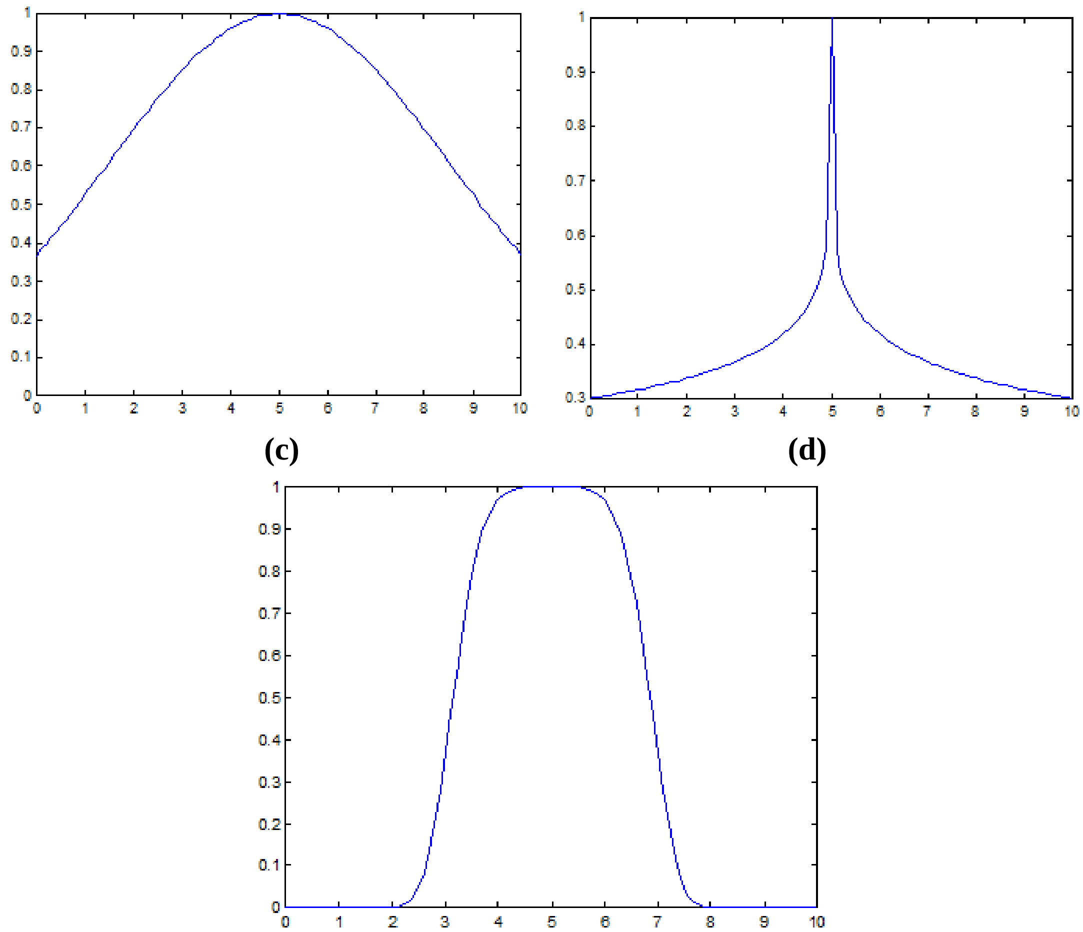
where c is the mean or refers to center in graph and s is the variance used to vary width of curve, m: fuzzification factor (generally m=2).



(a)



(b)



(c) **(d)**

(e)

Figure 2.1: Gaussian Membership function of a fuzzy set A with, **(a)** c=5, s=2, m=2; **(b)** c=5, s=0.5, m=2; **(c)** c=5, s=5, m=2; **(d)** c=5, s=2, m=0.2; **(e)** c=5, s=5, m=5

2.2 Related work in literature

The eye detection algorithm in [48] is composed of two main stages: face detection and face features extraction. Each processing stage makes use of colour information and spatial moment descriptors to detect the face and facial features.

Face detection stage consists of the skin segmentation as the first step. This approach uses the two color components (hue and saturation) of the HSL colour space to describe the colour of a possible skin pixel. Initially the acquired image has a colour representation in the RGB (red, green, blue) colour space which is being converted into HSL The three colour components in HSL are H (hue) that characterizes the colour of the skin, S (saturation) that gives the colour saturation, and L (luminance) which gives the illumination component.

The second step in face detection is that of Look up table for skin segmentation after colour conversion to HSL space, the image is processed using a look up table to emphasize skin regions contained by the image. Using this method image pixels are assessed, pixels described by colour components which have values in the specified intervals are highlighted, and the pixels with values outside the intervals are swapped to 0. Human skin is defined by any pixel whose colour components are within the intervals specified.

Parameters used in [48] for feature extraction: The algorithm implements a feature detection algorithm that detects the precise position for the eye centres based on certain measurements and rules:

Where δ' and δ are computed by the following method:

Considering any two pair of two particles well defined by their positions$a(x_2 - x_1), b(y_2 - y_1)$ the length δ' and the orientation α of the line segment determined by these points are calculated with the formula as:

$$\delta' = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad \textbf{…. (2.2 a)}$$

$$\alpha = \frac{180}{\pi} \, tan^{-1}\left(\frac{y_2 - y_1}{x_2 - x_1}\right) \quad \textbf{…. (2.2 b)}$$

And the reference distance between the eyes is determined by using the major and minor axis of the equivalent ellipse(an ellipse that has the same perimeter and area as the face region). Let p be the perimeter and A be the area of the region. Ellipse major and minor axis are calculated as :

$$E_a = \sqrt{\frac{p^2}{2\pi^2} + \frac{2A}{\pi}} + \sqrt{\frac{p^2}{2\pi^2} - \frac{2A}{\pi}} \quad \textbf{…. (2.2 c)}$$

$$E_b = \sqrt{\frac{p^2}{2\pi^2} + \frac{2A}{\pi}} - \sqrt{\frac{p^2}{2\pi^2} - \frac{2A}{\pi}} \quad \textbf{…. (2.2 d)}$$

The distance between the eyes used as reference by the eye detection stage is defined by the relation:

$$\delta = 0.575 * E_b \quad \textbf{…. (2.2 e)}$$

- The distance between the eyes meats the condition expressed with the given below, where ε defines the tolerance in length.

$$\delta' = \delta \pm \varepsilon, \quad \varepsilon = 15 \qquad \textbf{.... (2.2 f)}$$

- The orientation of line segment defined by the two points connecting the eye centres satisfies the constraint related to face orientation described by given formula. Theta θ expresses the tolerance for the orientation in degree.

$$\alpha = (r \pm 90) \pm \theta, \quad \theta = 4 \qquad \textbf{.... (2.2 g)}$$

where r is the face rotation which is computed by following formulas:

For each particle in the image, the following spatial properties are calculated: centre, perimeter and orientation. To determine these properties raw moments are computed first. Let I(x,y) be the image pixel intensities. The raw moments m_{ij} are calculated as:

$$m_{ij} = \sum_x \sum_y x^i y^j I(x, y) \qquad \textbf{.... (2.2 h)}$$

The moment m_{00} indicates the particle area $A = m_{oo}$. The particle centroid (center of mass) is also computed:

$$x_c = \frac{m_{10}}{m_{00}} \qquad \textbf{.... (2.2 i)}$$

$$y_c = \frac{m_{01}}{m_{00}} \qquad \textbf{.... (2.2 j)}$$

The central moments μ_{ij} which are translational invariant are calculated as:

$$\mu_{ij} = \sum_x \sum_y (x - x_c)^{\,i} (y - y_c)^{.j}\, I(x, y) \qquad \textbf{.... (2.2 k)}$$

The orientation of the particles is evaluated using the eigenvectors of covariance matrix:

$$cov[I(x, y)] = \begin{bmatrix} \mu'_{20} & \mu'_{11} \\ \mu'_{11} & \mu'_{02} \end{bmatrix} \qquad \textbf{.... (2.2 l)}$$

The eigenvectors of this matrix correspond to the major and minor axes of image intensity distribution, computed using:

$$\mu'_{20} = \frac{m_{20}}{m_{00}} - x_c^2 \quad \text{.... (2.2 m)}$$

$$\mu'_{02} = \frac{m_{02}}{m_{00}} - y_c^2 \quad \text{.... (2.2 n)}$$

$$\mu'_{11} = \frac{m_{11}}{m_{00}} - x_c y_c \quad \text{.... (2.2 o)}$$

The orientation is extracted from eigenvector associated with the largest distribution, determined by the relation:

$$\beta = \frac{1}{2}\, tan^{-1}\left(\frac{2\mu'_{11}}{\mu'_{20} - \mu'_{02}}\right) \quad \text{.... (2.2 p)}$$

Using the orientation β extracted from the eigenvector associated with the face region particle,we calculate the face rotation measures in degrees :

$$r = \frac{180 * \beta}{\pi} \quad \text{.... (2.2 q)}$$

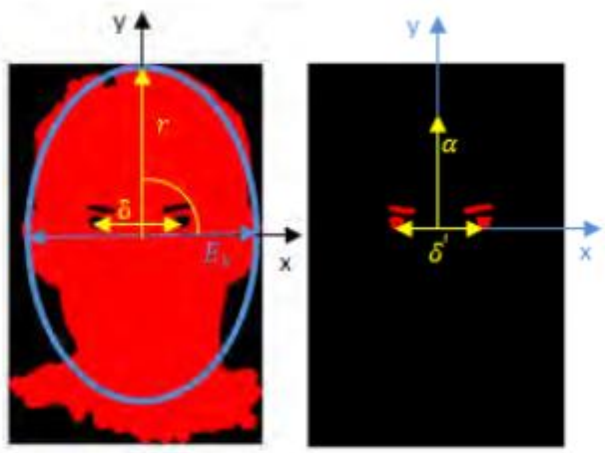


Fig.2.2 Parameters used in [48]

2.2.1 Drawbacks of the algorithm [48]

The approach used in the above paper is quite heuristic. Here distance between the particles is taken as one parameter to detect the eye pair and a tolerance of 15 pixels is given that can vary from one database to the other. Also the second parameter i.e. face orientation also varies from +4 to -4. Taking up such strict values is a heuristic concept.

The drawback of the given paper is a motivation of the presented work. The present work used a set of parameters that can detect eye pairs without any tolerance limits given to it.

2.3 Proposed fuzzy classifier for eye pair detection

Assuming that the face has been segmented as seen in fig.2.3 using suitable morphological processing techniques, the proposed fuzzy classifier acts on every possible pair of components in the segmented image to find the eye pair. To achieve this end eight geometrical facial features and their nine fuzzy memberships are computed for every possible pair as discussed below.

2.3.1 The eight geometrical facial features

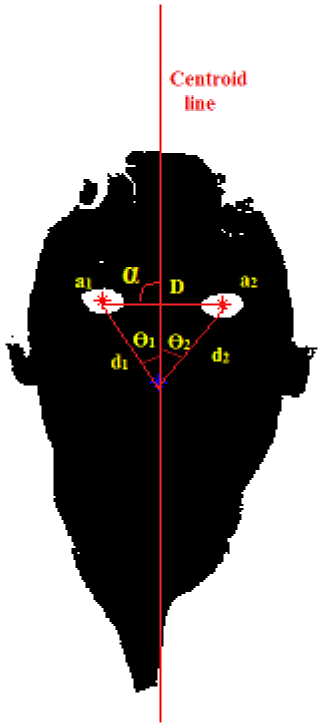


Fig.2.3 Proposed features for fuzzy eye pair detection algorithm

i. **Distance between eyes (D):** Distance between the two eye is calculated from the centre of the eyes and is represented as D as shown in fig.2.3

ii. **Distance between 1st eye and centroid (d_1):** It is the distance calculated from the center of the first eye to the centroid. The centroid shown by a blue star is the weighted centroid of the whole face. This value is represented as $\mathbf{d_1}$ as shown in fig.2.3

iii. **Distance between 2nd eye and centroid (d_2):** It is the distance calculated from the center of the second eye to the centroid. The centroid shown by a blue star is the weighted centroid of the whole face. This value is represented as $\mathbf{d_2}$ as shown in fig.2.3

iv. **Angle made by eyes with the vertical axis (α):** It is the angle formed by the line joining the two eyes and the vertical axis. The vertical axis is the vertical line passing through the centroid, thus called centroid line.

v. **Angle made by 1st eye and centroid with vertical axis (Θ_1):** This is the angle the first eye subtends at the centroid with the centroid line, represented as Θ_1 as shown in fig.2.3

vi. **Angle made by 2nd eye and centroid with vertical axis (Θ_2):** This is the angle the second eye subtends at the centroid with the centroid line, represented as Θ_2 as shown in fig.2.3

vii. **Area of 1st eye (a_1):** It is the area occupied by of first eye, represented as $\mathbf{a_1}$ in fig.2.3

viii. **Area of 2nd eye (a_2):** is the area occupied by of second eye, represented as $\mathbf{a_2}$ in fig.2.3

2.3.2 Nine fuzzy memberships based on the nine features:

We have chosen the Gaussian membership function to find the membership of each feature. The exponential function is given by:

$$\mu_i = e^{-\frac{(c_i - x_i)^2}{2\pi \sigma_i^2}} \qquad \text{…. (2.3)}$$

where, c_i : Feature vector

x_i : Mean value

σ_i : Standard Deviation

i. Membership of the distance between eyes :

$$\mu_1 = e^{-\frac{(D-x_1)^2}{2\pi\sigma_1^2}} \quad \text{…. (2.4 a)}$$

ii. Membership of the distance between 1st eye and centroid :

$$\mu_2 = e^{-\frac{(d1-x_2)^2}{2\pi\sigma_2^2}} \quad \text{.... (2.4 b)}$$

iii. Membership of the distance between 2nd eye and centroid :

$$\mu_3 = e^{-\frac{(d2-x_3)^2}{2\pi\sigma_3^2}} \quad \text{…. (2.4 c)}$$

iv. Membership of the angle made by eyes with the vertical axis:

$$\mu_4 = e^{-\frac{(\alpha-x_4)^2}{2\pi\sigma_4^2}} \quad \text{…. (2.4 d)}$$

v. Membership of the angle made by 1st eye and centroid with vertical axis:

$$\mu_5 = e^{-\frac{(\Theta1-x_5)^2}{2\pi\sigma_5^2}} \quad \text{…. (2.4 e)}$$

vi. Membership of the angle made by 2nd eye and centroid with vertical axis:

$$\mu_6 = e^{-\frac{(\Theta2-x_6)^2}{2\pi\sigma_6^2}} \quad \text{…. (2.4 f)}$$

vii. Membership of the area of 1st eye :

$$\mu_7 = e^{-\frac{(a_1-x_7)^2}{2\pi\sigma_7^2}} \quad \text{…. (2.4 g)}$$

viii. Membership of the area of Area of 2nd eye :

$$\mu_8 = e^{-\frac{(a_2-x_8)^2}{2\pi\sigma_8^2}} \quad \text{…. (2.4 h)}$$

ix. Matching of the two areas

$$\mu 9 = e^{-\frac{(a_1-a_2)^2}{2\pi\sigma_7\sigma_8}} \quad \text{…. (2.4 i)}$$

Where, $\mathbf{x_1}$, $\mathbf{x_2}$, $\mathbf{x_3}$, $\mathbf{x_4}$, $\mathbf{x_5}$, $\mathbf{x_6}$, $\mathbf{x_7}$, $\mathbf{x_8}$ are mean values of the respective features and $\boldsymbol{\sigma_1}$, $\boldsymbol{\sigma_2}$, $\boldsymbol{\sigma_3}$, $\boldsymbol{\sigma_4}$, $\boldsymbol{\sigma_5}$, $\boldsymbol{\sigma_6}$, $\boldsymbol{\sigma_7}$, $\boldsymbol{\sigma_8}$ are standard deviations.

2.3.3 Processing of the fuzzy memberships.

All the memberships obtained from the above steps are added up for each possible pair in the segmented face and the maximum out of them is selected for detecting the eye pair. The same is shown in the block diagram below:

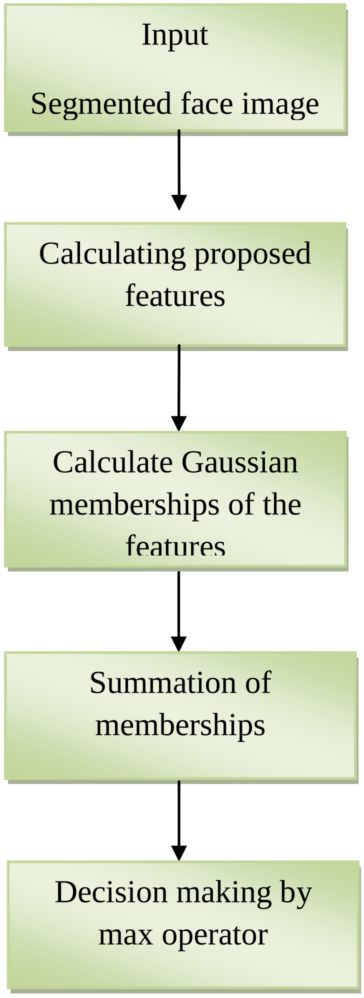


Fig.2.4 flowchart of proposed algorithm

The eye detection algorithm can be summarized as:

Step 1: the segmented face image as input.

Step 2: For the given input image compute the features discussed in section 2.3. These parameters are to be calculated for each possible pair of connected component we have in the input image.

Step 3: find the fuzzy membership of the features obtained from step 2. The proposed method uses Gaussian fuzzy membership given is section 2.3.

Step 4: finding the summation of the 9 fuzzy memberships. Summation of Gaussian memberships is given by equation:

$$S_p = \sum_{i=1}^{9} \mu_i \qquad \textbf{…. (2.5)}$$

Where, S_p is the summation of all the memberships $\mu_{1,2,\ldots9}$

p is the number of possible pairs of connected components in the image.

Step 5: applying fuzzy operator to find the eye pair. The decision making is performed by using max operator. The max operator is a fuzzy t-conorm operator. Triangular norms and conorms are operations which generalize the logical conjunction and logical disjunction to fuzzy logic. They are a natural interpretation of the conjunction and disjunction in the semantics of mathematical fuzzy logics [51] and they are used to combine criteria in multi-criteria decision making. The proposed method uses maximum or Gödel t-conorm operator given by the equation:

$$M = \underset{\forall p}{Max} \{S_p\} \qquad \text{….(2.6)}$$

The output we obtain is the eye pair detected in the face image. The results of the proposed algorithm are shown in chapter 4.

CHAPTER-3

COMPARISON METHODS

3.1 Neural networks

What is Neural Network?

A neural net is an artificial representation of the human brain that tries to simulate its learning process. An artificial neural network (ANN) is often called a "Neural Network" or simply Neural Network (NN). Traditionally, the word neural network is referred to a network of biological neurons in the nervous system that process and transmit the information.

Artificial Neural Network is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on a connectionist approach to computation. The artificial neural networks are made of interconnecting artificial neurons which may share some properties of biological neural networks. It is thus an adaptive system that changes its structure based on external or internal information that flows through the network.

A neural network can thus be defined as a form of multiprocessor computer system, with

- Simple processing elements,
- A high degree of interconnection,
- Simple scalar messages, and
- Adaptive interaction between elements.

3.1.1 History of Neural Networks

McCulloch and Pitts(1943) are generally recognized as the designers of the first neural networks. They combined many simple processing units together that could lead to an overall increase in computational power. They suggest many ideas like: a neuron has a threshold level and once that level is reached the neuron fires. It is still a fundamental way in which ANNs operate. The McCulloch and Pitt's network had a fixed set of weights.

Hebb (1949) developed the first learning rule that is if two neurons are active at the same time then the strength between them should be increased. Similarly there were many researchers like Block, Minsky, Papert and Rosenblant who worked on perceptron in 1950 and 60's.Minsky and Papert (1969) showed perceptron could not learn those functions that are not linearly separable. Neural Network research declined through 1970's and mid 80's because perceptron could not learn important functions. But it regained importance in 1985-86.Parker and LeCun discovered a learning algorithm for multi-layer networks called back propagation that could solve linearly inseparable problem.

3.1.2 Artificial Neuron model

An Artificial Neuron is a mathematical function conceived as a simple model of real biological neuron.

The McCulloch-Pitts Neuron:

This is a simplified model of real neurons, known as a Threshold Logic Unit.

- A set of input connections brings in activations from other neurons.
- A processing unit sums the input, and then applies a non linear activation function (i.e. squashing / transfer / threshold function).
- An output line transmits the result to other neuron.

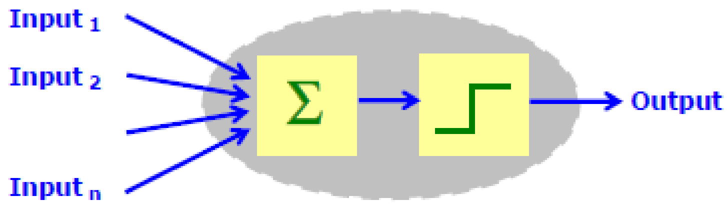


Fig.3.1 Simplified model of Real Neuron (Threshold logic unit)

The equation for output of a McCulloch Pitts neuron as a function of 1 to n inputs is written as

$$Output = sgn(\sum_{i=1}^{n} Input_{\,i} - \phi) \qquad \textbf{.... (3.1)}$$

Where ϕ is the neurons's activation threshold.

If $\sum_{i=1}^{n} Input_{\,i} \geq \phi$ then Output = 1

If $\sum_{i=1}^{n} Input_{\,i} \leq \phi$ then Output = 0

In this McCulloch-Pitts model, the missing features are:

- Non-binary input and output,
- Non-linear summation,
- Smooth thresholding
- Stochastic, and
- Temporal information processing

Artificial Neuron-Basic Element: Neuron consists of 3 basic components – weights, threshold and a single activation function.

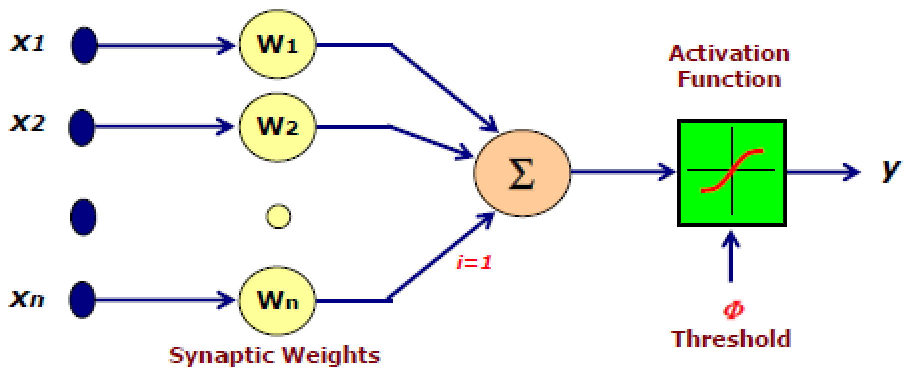


Fig.3.2 Basic Element of an Artificial Neuron

- **Weighting Factor w**: The values $w_1, w_2, \ldots. w_n$ are weights to determine the strength of input vector $X = [x_1, x_2, \ldots, x_n]^T$. Each input is multiplied by the associated weight of the neuron connection $X^T W$. The +ve weight excites and the –ve weight inhibits the node output.
- **Threshold ϕ**

  The node's internal threshold ϕ is the magnitude offset. It affects the activation of the node output y as:

$$Y = f(I) = f\{ \sum_{i=1}^{n} x_i w_i - \phi_k \} \qquad \textbf{.... (3.2)}$$

To generate the final output Y, the sum is passed on to a non-linear filter f called Activation Function or Transfer Function or Squash Function which releases the output Y.

- **Activation Function**

Neurons generally do not fire (produce output) unless their total input goes above a threshold value. The total input for each neuron is the sum of the weighted inputs to the neuron minus its threshold value. This is then passed through the sigmoid function. The equation for the transition in a neuron is:

$$a = \frac{1}{(1 + \exp(-x))} \qquad \textbf{…. (3.3)}$$

Where $x = \sum_i a_i \, w_i - Q$

a is the activation for the neuron

a_i is the activation for neuron i

w_i is the weight

Q is the threshold subtracted

An activation function f performs a mathematical operation on the signal output. The most common activation functions are: Linear Function, Piecewise Linear Function, Tangent hyperbolic function, Threshold function. These are chosen depending upon the type of problem to be solved by the network.

Sigmoidal Activation function: the non linear curved S-shape function is called the sigmoid function. This is the most common type of activation used to construct the neural networks. It is mathematically well behaved, differentiable and strictly increasing function.

A sigmoidal transfer function can be written in the form:

$$Y = f(I) = \frac{1}{1+e^{-\propto I}} \quad ,0 \leq f(I) \leq 1 \qquad \textbf{…. (3.4)}$$

$$= \frac{1}{1 + \exp(-\propto I)} \quad ,0 \leq f(I) \leq 1$$

This is explained as

≈ 0 For large –ve input values,

1 for large +ve values, with a smooth transition between the two.

∝ is slope parameter also called shape parameter ;

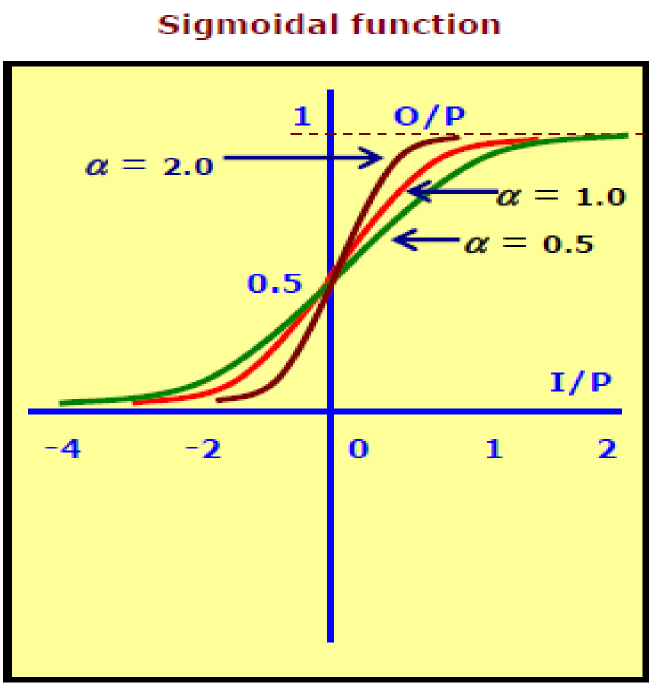


Fig.3.3 Sigmoidal function

Based on the type of architecture neural networks can be classified into different categories:

- Single layer feed forward Network
- Multilayer feed forward Network
- Recurrent Networks

3.1.3 Neural Network Pattern Recognition

A pattern could be a fingerprint image, a handwritten cursive word, a human face, or a speech signal. Given a pattern, its recognition/classification may consist of one of the following two tasks:

1) Supervised classification (e.g., discriminant analysis) in which the input pattern is identified as a member of a predefined class,

2) Unsupervised classification (e.g., clustering) in which the pattern is assigned to a hitherto unknown class.

The design of a pattern recognition system essentially involves the following three aspects:

1) Data acquisition and pre-processing,

2) Data representation, and

3) Decision making.

The problem domain dictates the choice of sensor(s), pre-processing technique, representation scheme, and the decision making model. It is generally agreed that a well-defined and sufficiently constrained recognition problem (small intraclass variations and large interclass variations) will lead to a compact pattern representation and a simple decision making strategy. Learning from a set of examples (training set) is an important and desired attribute of most pattern recognition systems. The four best known approaches for pattern recognition are: 1) template matching, 2) statistical classification, 3) syntactic or structural matching, and 4) neural networks

The most commonly used family of neural networks for pattern classification tasks [52] is the feed-forward network, which includes multilayer perceptron and Radial-Basis Function (RBF) networks. Another popular network is the Self-Organizing Map (SOM), or Kohonen-Network [53], which is mainly used for data clustering and feature mapping. The learning process involves updating network architecture and connection weights so that a network can efficiently perform a specific classification/clustering task.

Here the pattern recognition task is done by using a 2 layer feed forward neural network as shown in fig.3.4 with sigmoid output neurons.

Besides having input and output layers, also have one or more intermediary layers or hidden layers. The computational units of the hidden layer are known as hidden neurons.

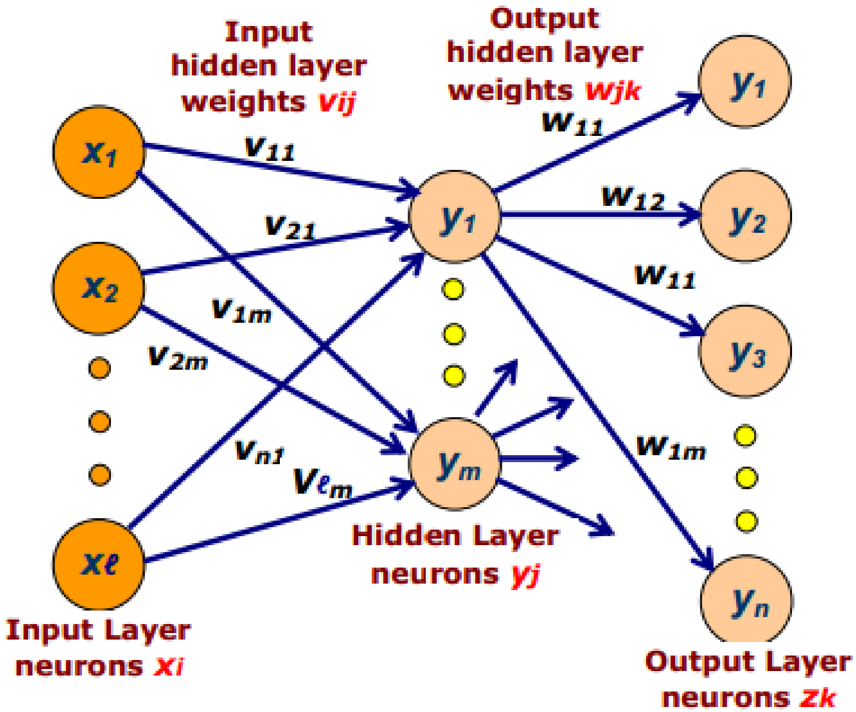


Fig.3.4 Multilayer feed forward network

The training of an MLP is usually accomplished by using a back propagation (BP) algorithm that involves two phases (Werbos 1974[54]; Rumelhart et al. 1986):

• Forward Phase. During this phase the free parameters of the network are fixed, and the input signal is propagated through the network of Fig. 3.4 layer by layer. The forward phase finishes with the computation of an error signal

$$e_i = d_i - y_i \qquad \textbf{.... (3.5)}$$

where d_i is the desired response and y_i is the actual output produced by the network in response to the input x_i.

• Backward Phase. During this second phase, the error signal e_i

Is propagated through the network of Fig. 3.4 in the backward direction, hence the name of the algorithm. It is during this phase that adjustments are applied to the free parameters of the network so as to minimize the error e_i in a statistical sense. Back-propagation learning may be implemented in one of two basic ways, as summarized here:

1. Sequential mode (also referred to as the on-line mode or stochastic mode): In this mode of BP learning, adjustments are made to the free parameters of the network on an example-by example basis. The sequential mode is best suited for pattern classification.

2. Batch mode: In this second mode of BP learning, adjustments are made to the free parameters of the network on an epoch-by-epoch basis, where each epoch consists of the entire set of training examples. The batch mode is best suited for nonlinear regression.

3.2 Eye Variance Filter:

3.2.1 Variance:

In probability theory and statistics, the ***variance*** is a measure of how far a set of numbers is spread out. It is one of several descriptors of a probability distribution, describing how far the numbers lie from the mean (expected value). In particular, the variance is one of the moments of a distribution. In that context, it forms part of a systematic approach to distinguishing between probability distributions. While other such approaches have been developed, those based on moments are advantageous in terms of mathematical and computational simplicity.

3.2.2 Using variance for eye detection

Eye detection becomes a challenging task because of two reasons. Firstly it is an active model constructed by an eyeball and two eyelids. Another reason is that the edge feature on this region is not clearly visible. Eyes can be detected because the change of grey intensity on this region is more obvious than other regions on the human face. The variance on a domain indicates the measurement of the grey intensity variation. Feng[25]2005 developed a method for detecting eyes using eye variance filter by first roughly estimating eye windows and then applying the eye variance filter on that window. Wang and yang [75] presented an eye detection method for facial images in 2006.

By using this statistic we form a variance filter. The objective of this variance filter is to precisely extract the two eyes in the eye region. The variance filter is computed for both the left and right eye since the two eyes have different structures. The obtained variance filter is applied to each of the left half and the right half of the test image separately.

(a) (b)

Fig.3.5 (a) Original image **(b)** Cropped eye

3.2.3 Construction of eye variance filter:

Let I (x,y) be an eye image, the variance on a domain Ω is defined as

$$\sigma_{\Omega}^{2} = \frac{1}{A_{\Omega}} \Sigma \left[I(x,y) - \overline{I_{\Omega}} \right]^{2} \qquad \text{…. (3.6)}$$

Where, A_{Ω} and $\overline{I_{\Omega}}$ represent area and average grey intensity on a domain Ω.

The definition of σ_{Ω}^{2} describe its two properties:

1) It is rotation invariant in domain Ω.
2) σ_{Ω}^{2} reflects grey intensity variations rather than the exact shape on the domain.

To construct eye variance filter, we select 10 left eye window and 10 right eye windows of size 56 X 56 from different persons as a training image set. The centers of eye balls are aligned manually.

For each 56X56 image, a 8x8 overlapping block are selected and the eye variance images of size 7X7 is obtained.

The eye variance filter is constructed by calculating the average of the variance images.

$$F_{e} = \frac{1}{N} \Sigma \left[\sigma_{\Omega}^{2} \right] \qquad \text{…. (3.7)}$$

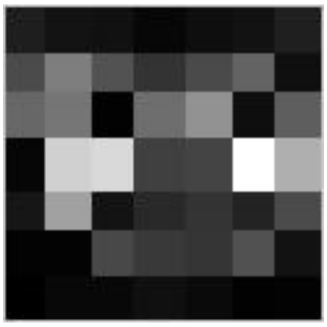
3.2.4 Evaluation of eye variance filter:

To detect the potential eye windows using an eye variance filter, a correlation is calculated between the filter and each variance image block.tht eye separately. This process is done individually for the left half and the right half of the image to obtain the left eye and the right eye separately. The correlation is defined as follows:

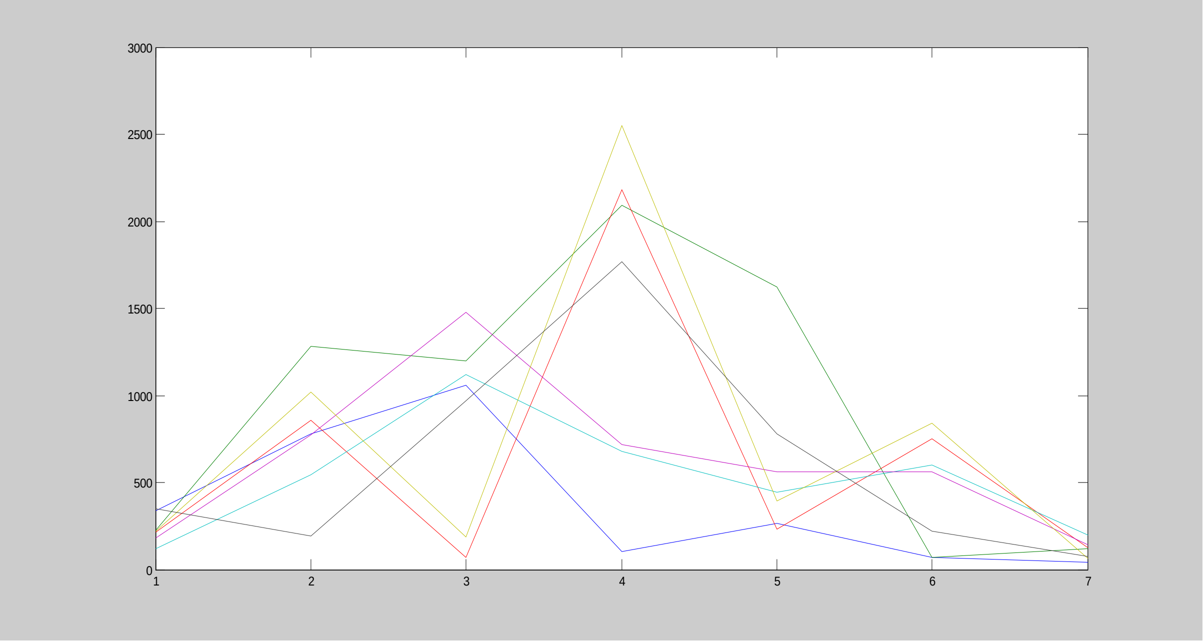
$$R(I_{\sigma_i}, F_e) = \frac{E\left(\xi_{I_{\sigma i}} - E\left(\xi_{I_{\sigma i}}\right)\right)\left(\xi_{F_e} - E(\xi_{F_e})\right)}{\sqrt{D\left(\xi_{I_{\sigma i}}\right)D(\xi_{F_e})}} \quad \text{.... (3.8)}$$

where $\xi_{I_{\sigma i}}$ and ξ_{F_e} are the concatenated vectors of the variance image $I_{\sigma i}$ and F_e, respectively, $I_{\sigma i}$ is an image block, and $E(.)$ and $D(.)$ represent the mathematical expectation and variance of the random variable. The related coefficient between the eye variance filter and each image block is calculated. The maximum related coefficient is then compared with the threshold determined by all of the related coefficients obtained in the experiment. If the maximum related coefficient is greater than the threshold, the eye is detected. If the maximum related coefficient is less than the threshold, the detection fails. The proposed eye variance filter can extract two eyes precisely if the change of grey intensity on eye region is normal.

To detect two eyes in the eye region, the extracted eye image, shown in Fig. 3.5(b), is transformed into a variance image, shown in Fig. 3.6 (a). 2D plot of the eye variance filter with is shown in Fig. 3.6(b).



(a)



(b)

Fig. 3.6 (a) Eye variance filter (7x7) **(b)** 2D plot of eye variance filter (intensity Vs pixel)

CHAPTER 4:
RESULTS

The proposed algorithm is processed under MATLAB version 7.9.0(R2009b) and on Intel(R) Core(TM) i3 processor with 3 GB RAM. The face database [32] used is collection of 131 colored images out of which the proposed algorithm is tested on 65 individuals. The images are collected at the European Conference on Visual Perception in Utrecht, 2008 having resolution 900x1200.

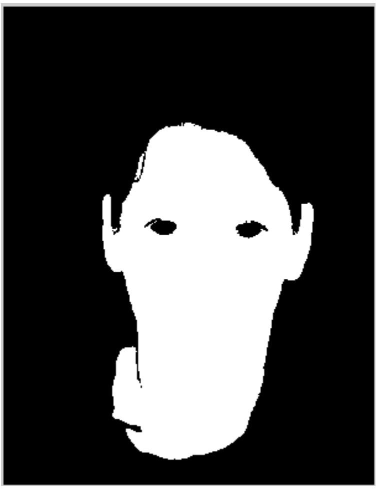
4.1 Results of the Proposed Algorithm

The process starts with the original RGB image. This RGB image is first converted into LAB color model. The reason we chose lab color model is the color of human skin. Color transformed image is thresholded by using Otsu thresholding as shown in fig 4.1.

(a)

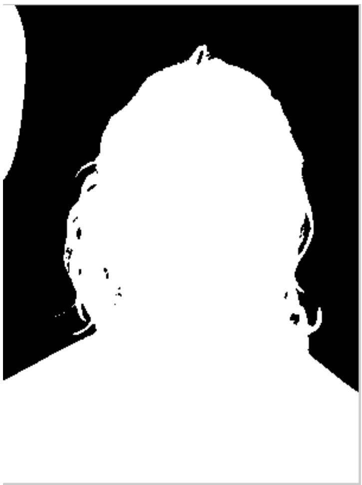
(b)

(c)

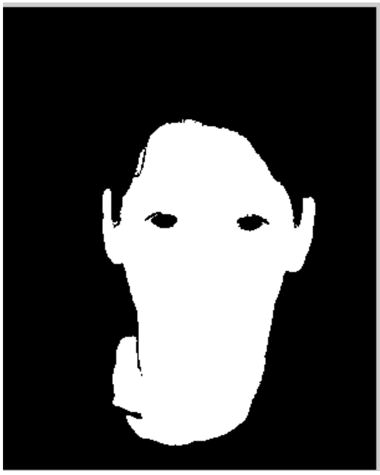


(d)

(e)



(f)



(g)

Fig.4.1 (a) Original image **(b)** Color transformed image **(c)** Fig. a* component **(d)** thresholded a* image **(e)** b* component **(f)** thresholded b* component **(g)** final segmented image

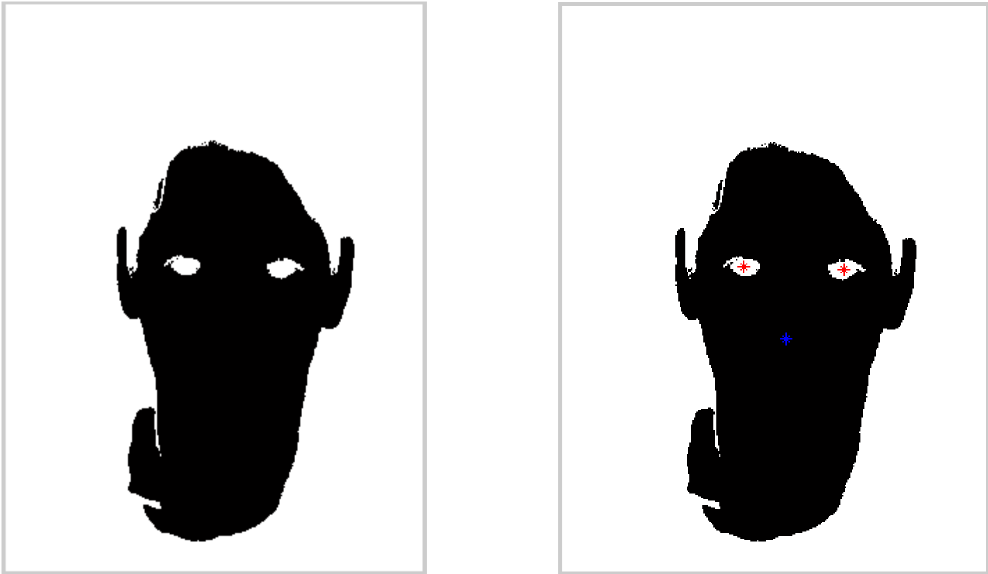
Out of the 65 images, 10 images are selected as training images shown in fig.4.2 and all the features of these 10 images are calculated .For all the features we calculate the mean and standard deviation for the training database which is used for localizing the eye pair in test image using fuzzy logic as shown in table 4.1 .

Fig. 4.2 Training database

Table 4.1 Mean and Standard Deviation (S.D) of the eight features obtained from training database

Features / Images	**D**	**d_1**	**d_2**	**Ɵ**	**$Ɵ_1$**	**$Ɵ_2$**	**a_1**	**a_2**
1st	179.42	81.46	96.46	92.16	33.44	39.50	1802	1756
2nd	214.16	89.59	123	91.68	30.10	39.54	2101	2085
3rd	222.15	121.80	99	94.08	42.03	39.73	2216	2308
4th	184.11	94.74	87.6	90.91	31.56	30.11	1644	1681
5th	216.79	105.79	110.12	88.80	50.24	49.96	1850	1745
6th	194.64	85.11	108.49	90.95	41.33	49.16	1384	1309
7th	201.84	100.39	100.59	88.35	53.32	51.32	1479	1591
8^{th}	180.96	80.02	99.45	92.08	32.95	40.28	1827	1853
9^{th}	200.49	120.39	78.16	88.31	35.14	24.02	913	1177
10^{th}	210.19	86.13	122.82	92.10	37.33	49.28	1667	1774
Mean	200.51	96.54	102.58	90.94	38.74	41.29	1688	1727
S.D	15.50	15.26	14.14	1.90	7.92	9.03	372.23	330.45

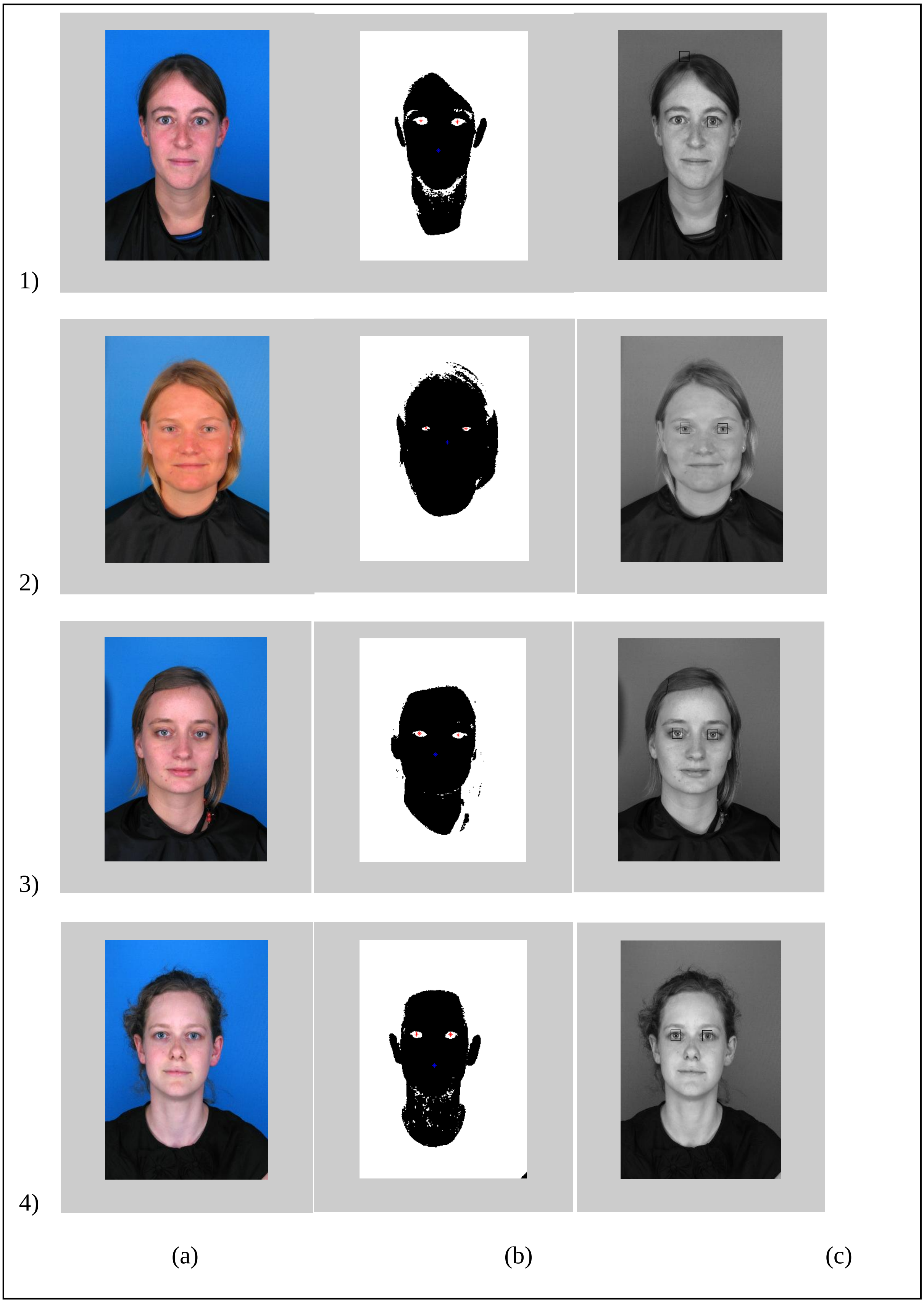
The next step is to input a test image and perform all the steps was discussed in Section 2.3 and 2.4. The resultant image consists of red points indicating eyes as shown.

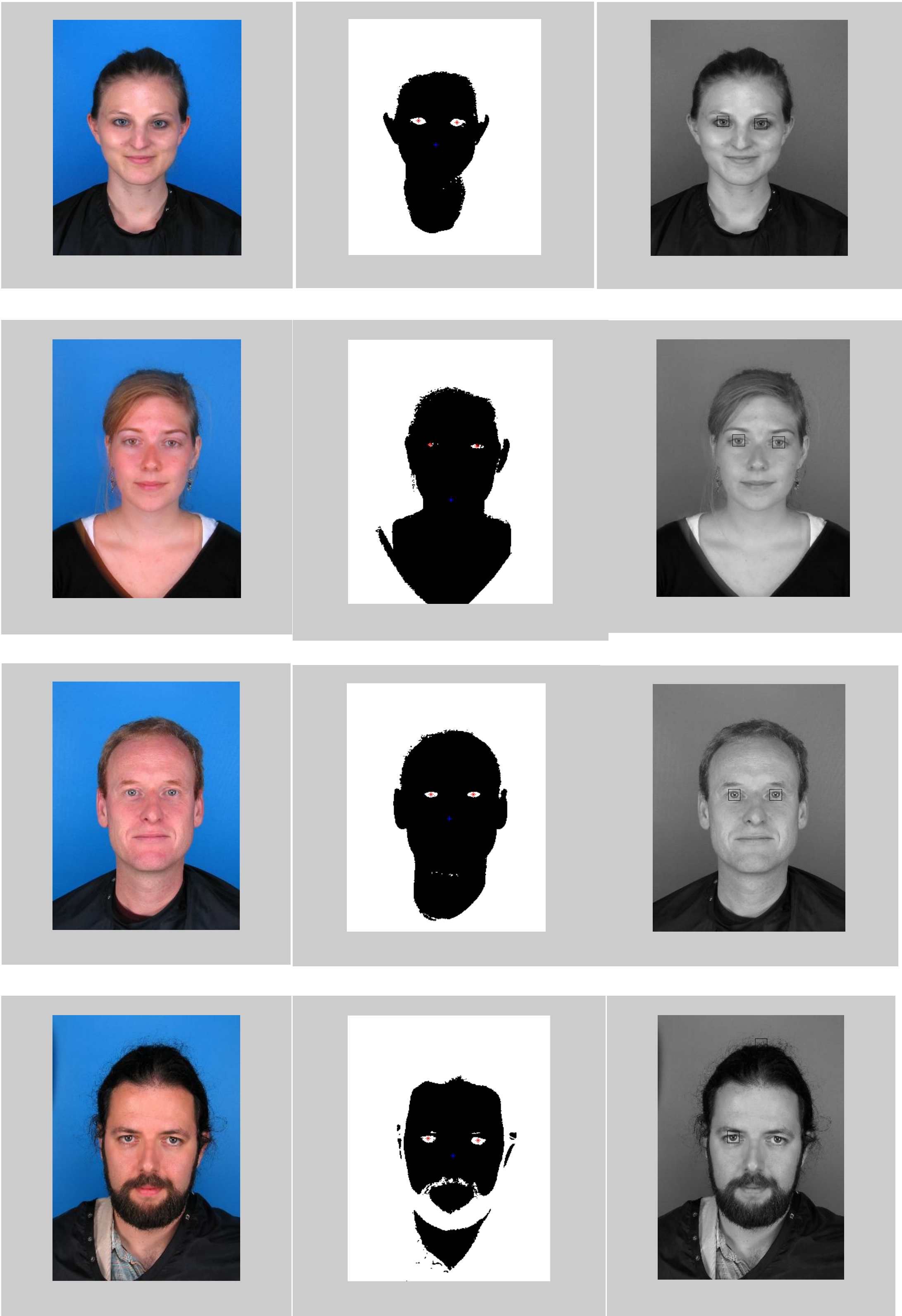


(a) (b)

Fig. 4.3 (a) Final Segmented image of 4.1 (a) **(b)** Eye pair detected of 4.3 (a)

The proposed fuzzy eye pair detection algorithm has accuracy of 96.36% since it is detecting eye pairs of 53 images out of 55 input images. The results of the proposed method and the eye variance filter are shown in fig. 4.4.


1)
2)
3)
4)
(a)
(b)
(c)



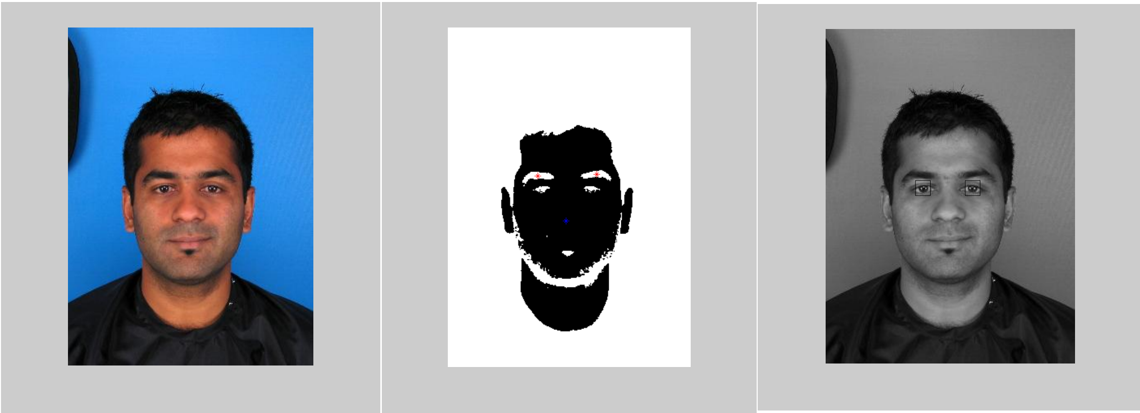
5)

6)

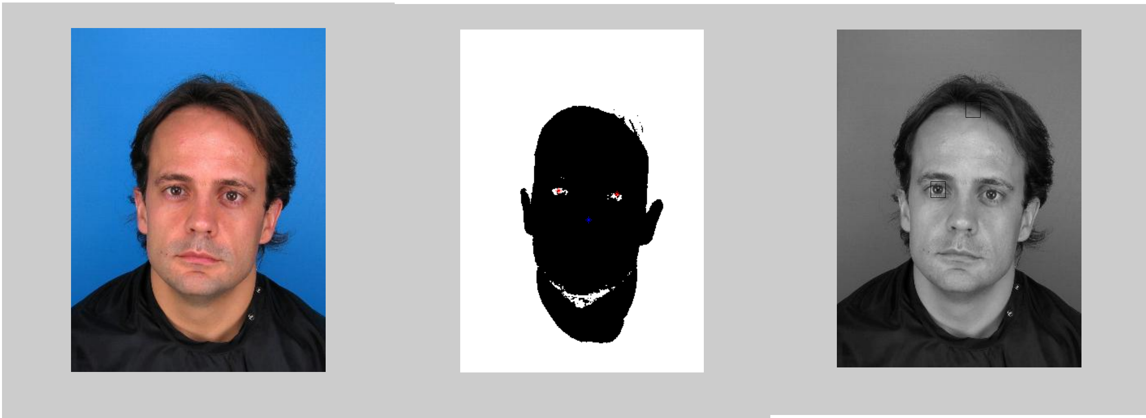
7)

8)

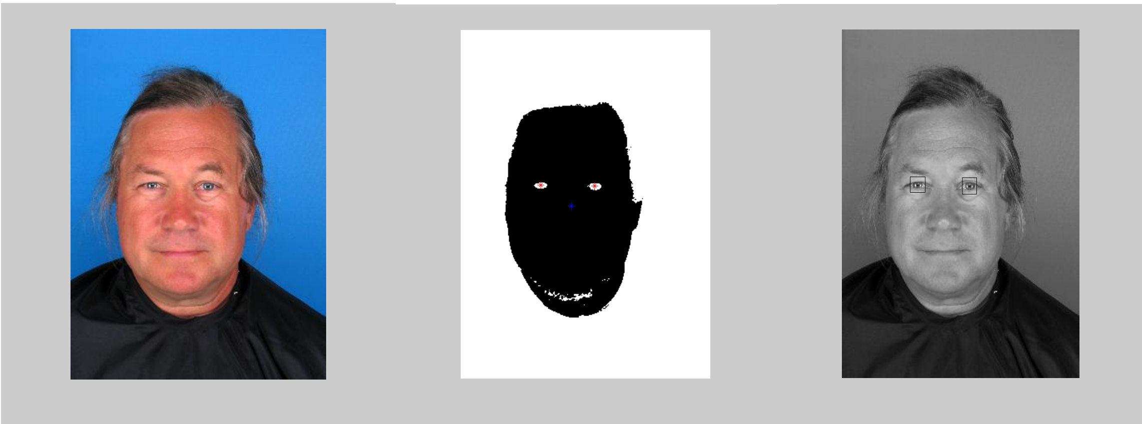
(a) (b) (c)



9)



10)



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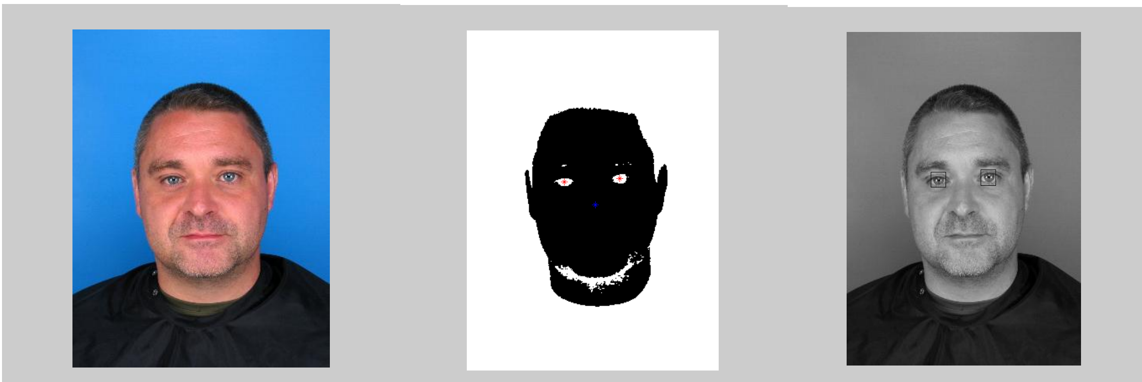

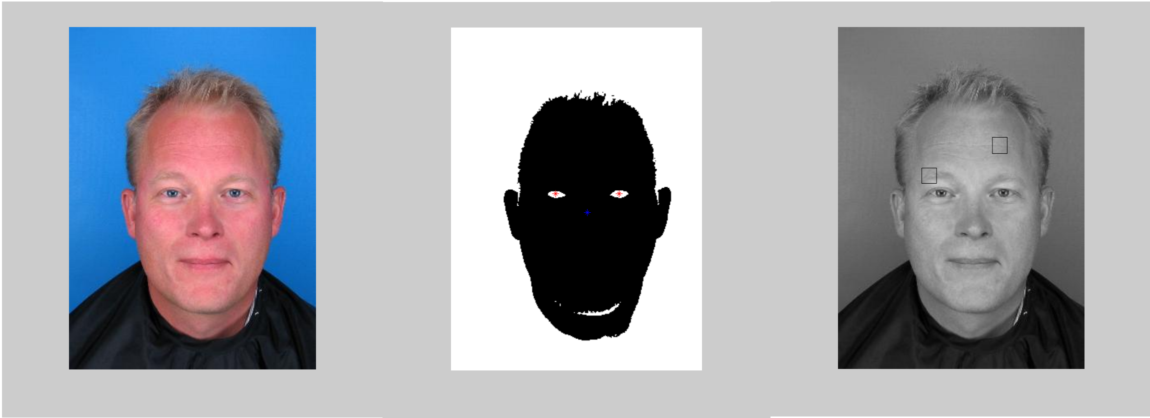

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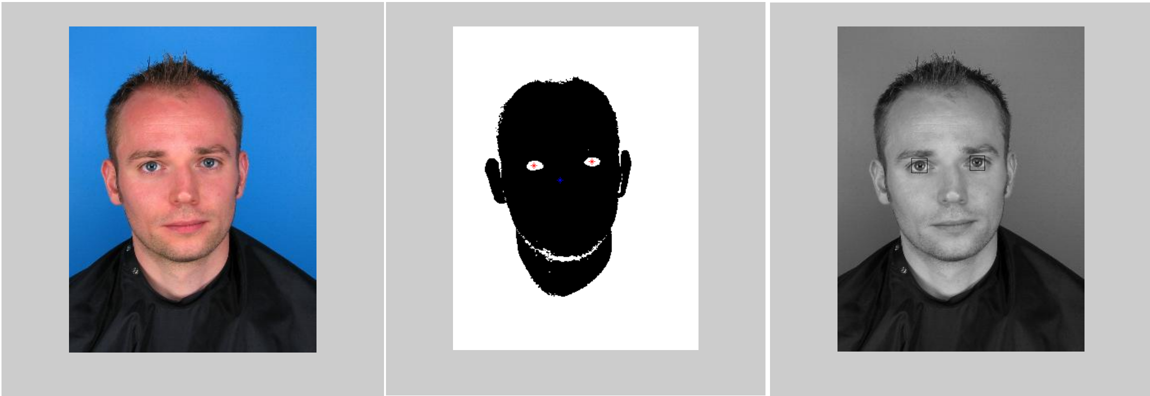

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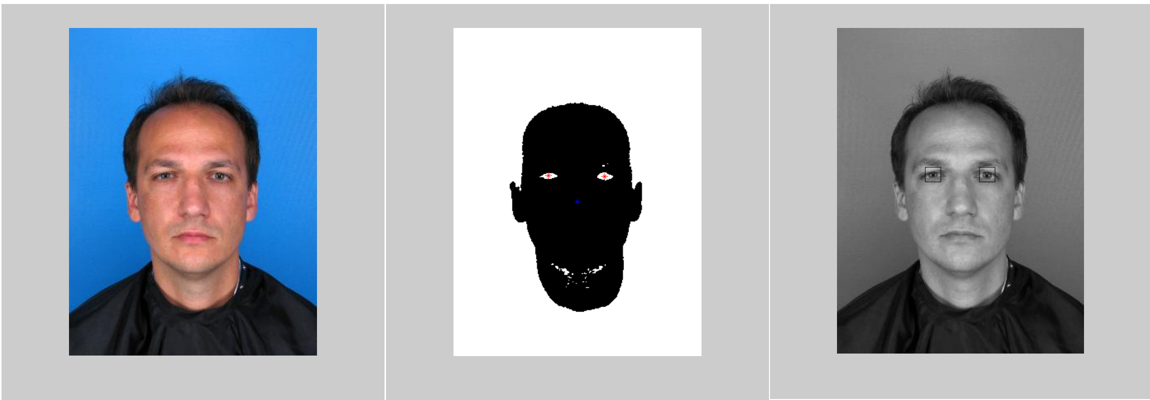

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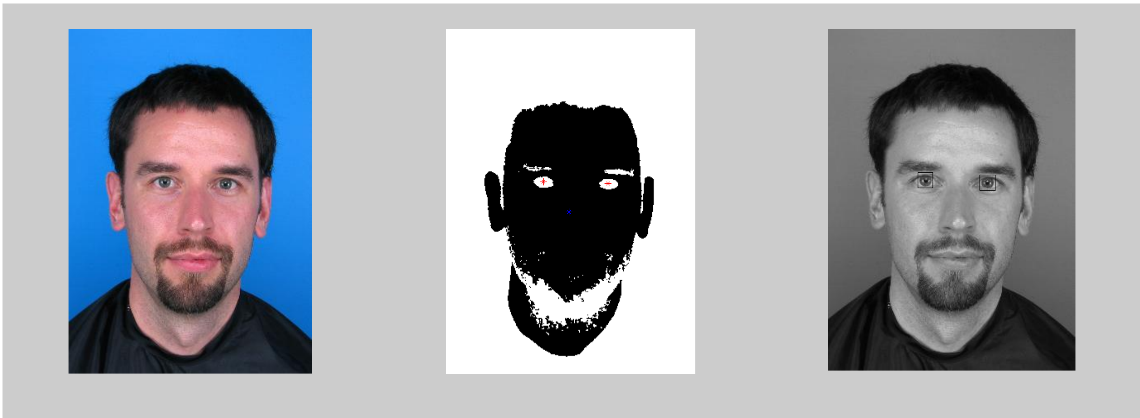
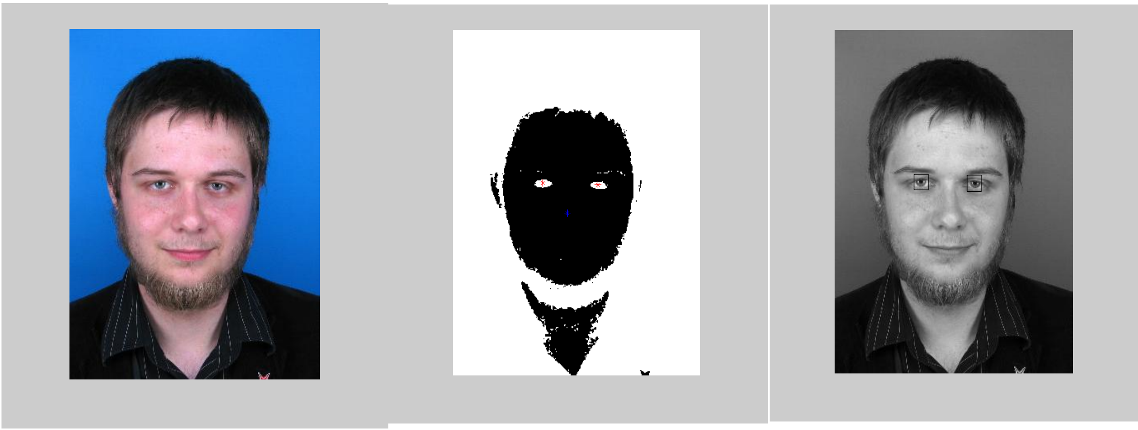
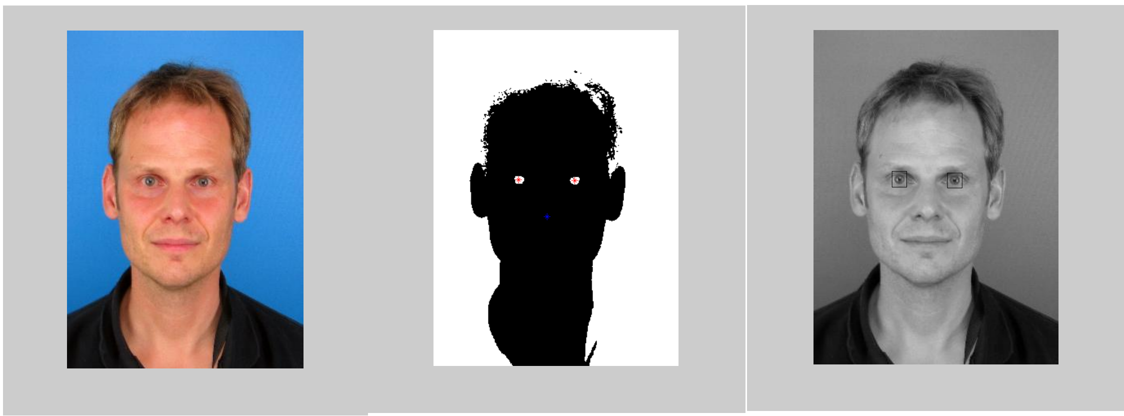


16)

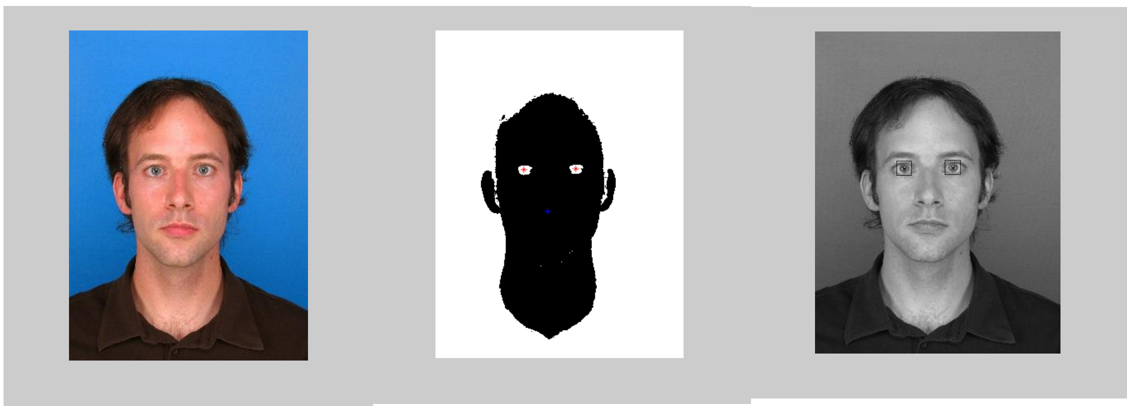
(a) (b) (c)



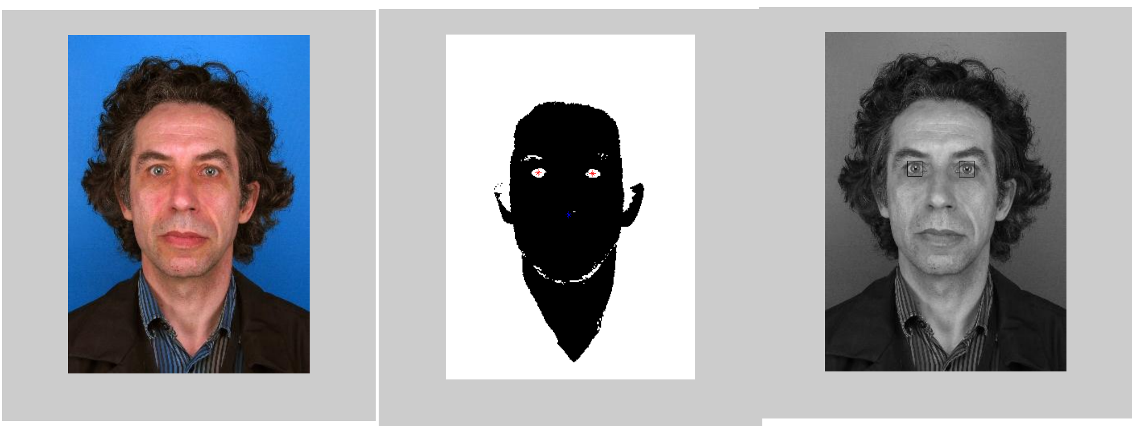
17)



18)

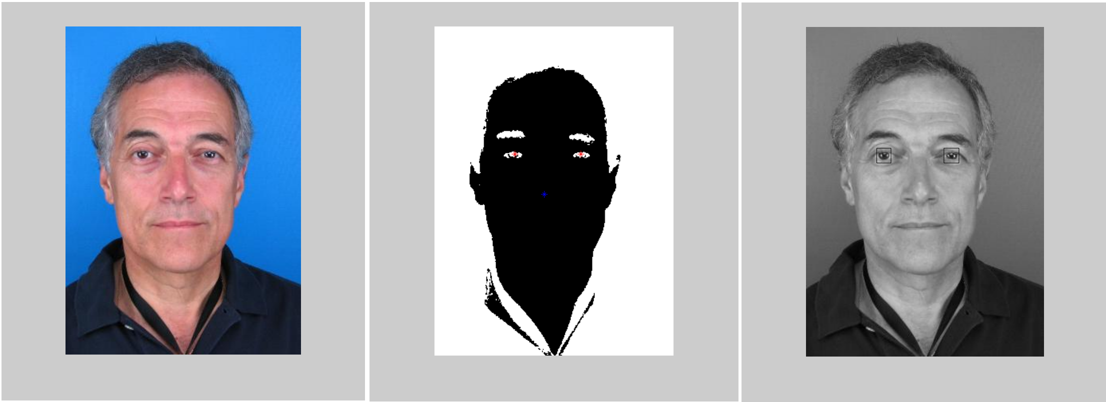


19)

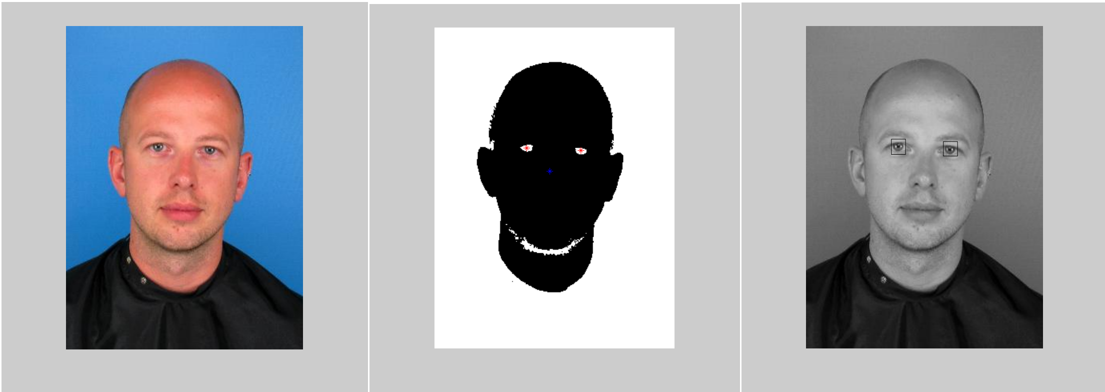


20)

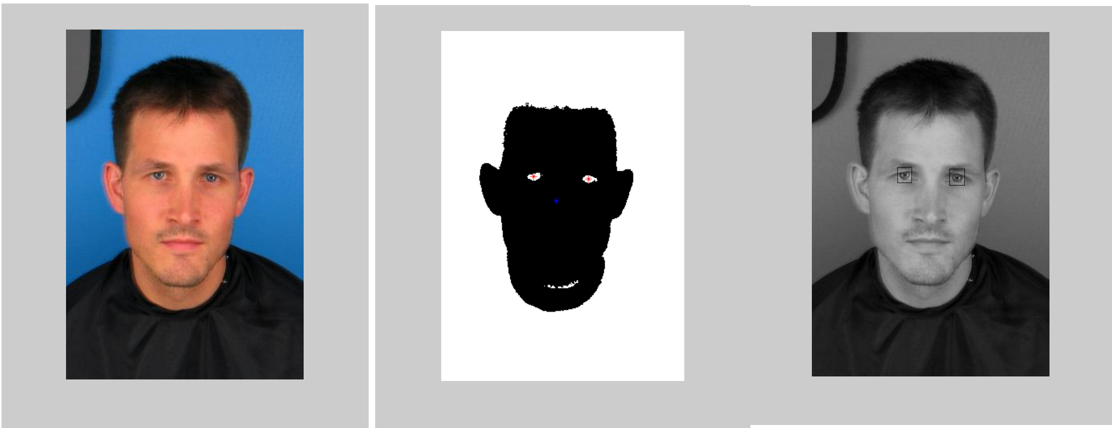
(a) (b) (c)



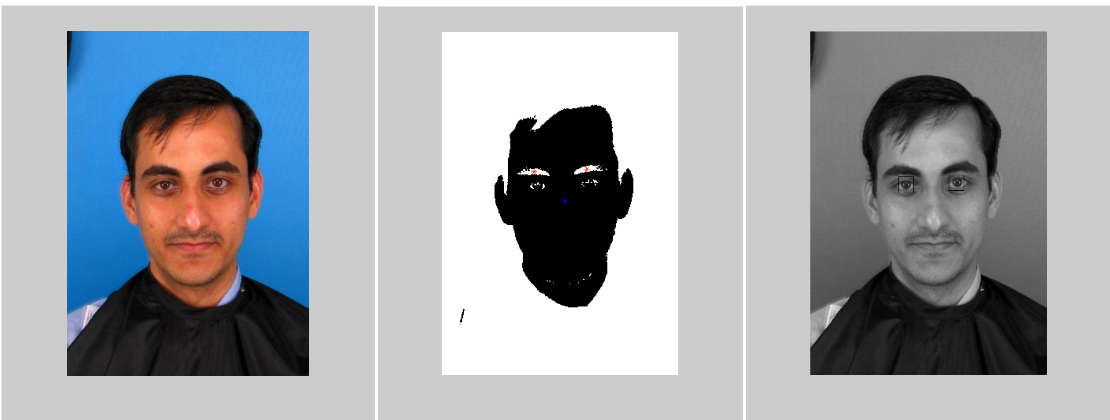
21)



22)

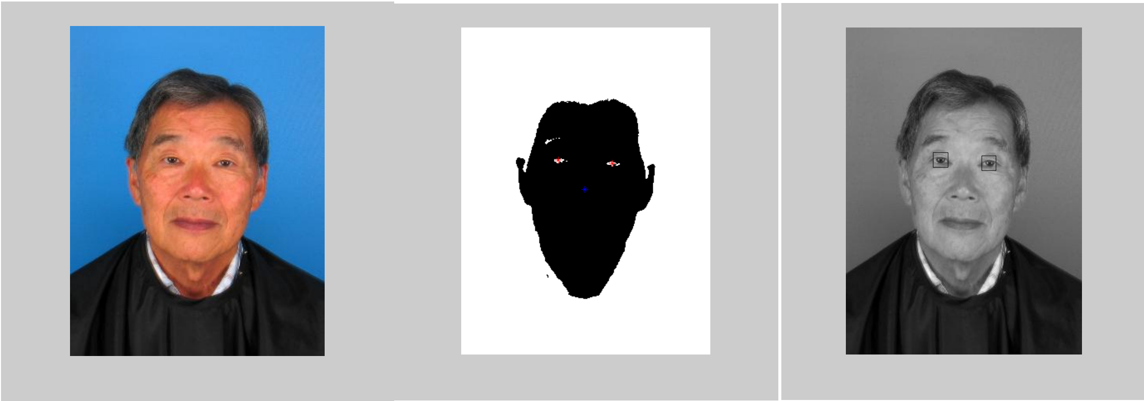


23)

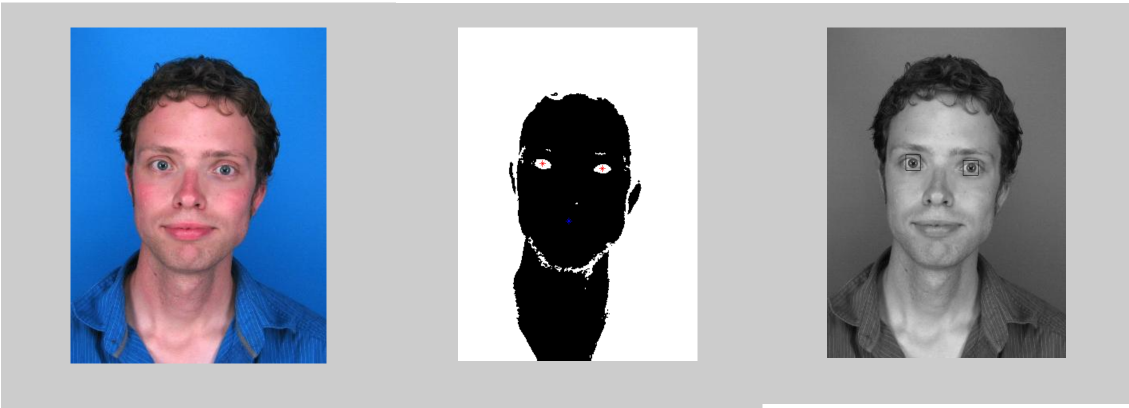


24)

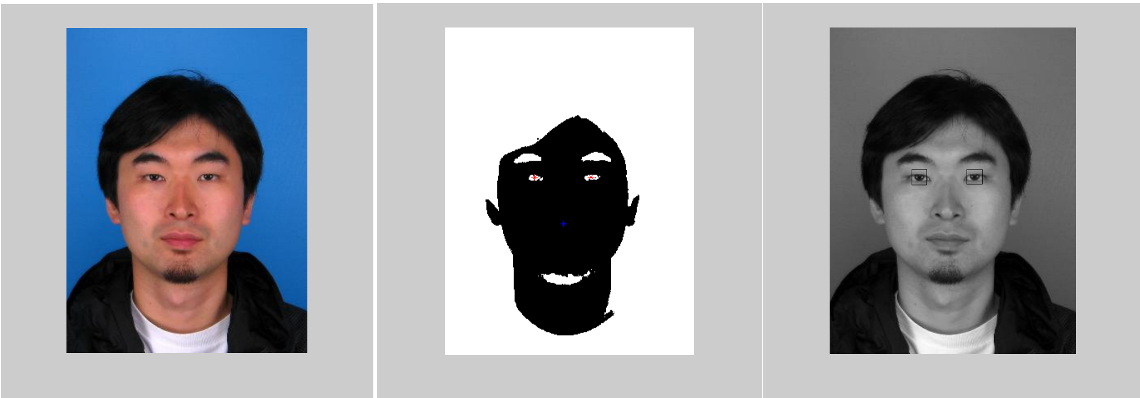
(a) (b) (c)



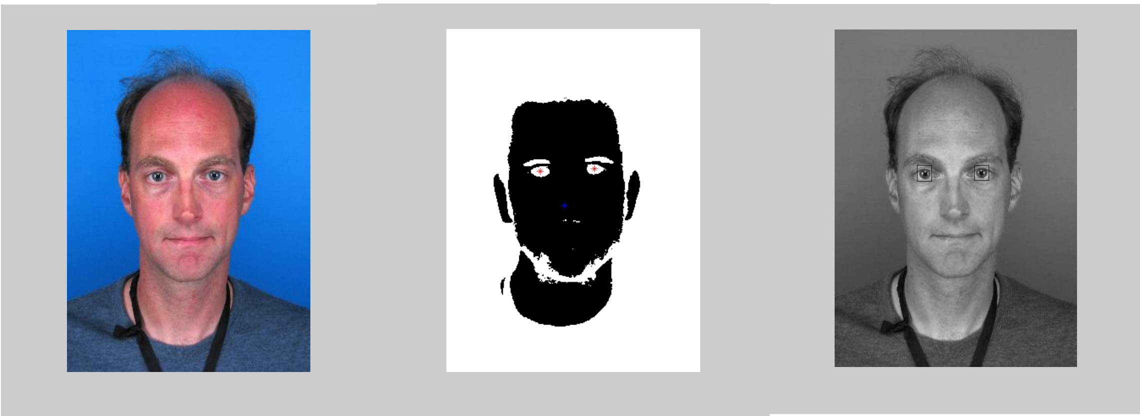
25)



26)

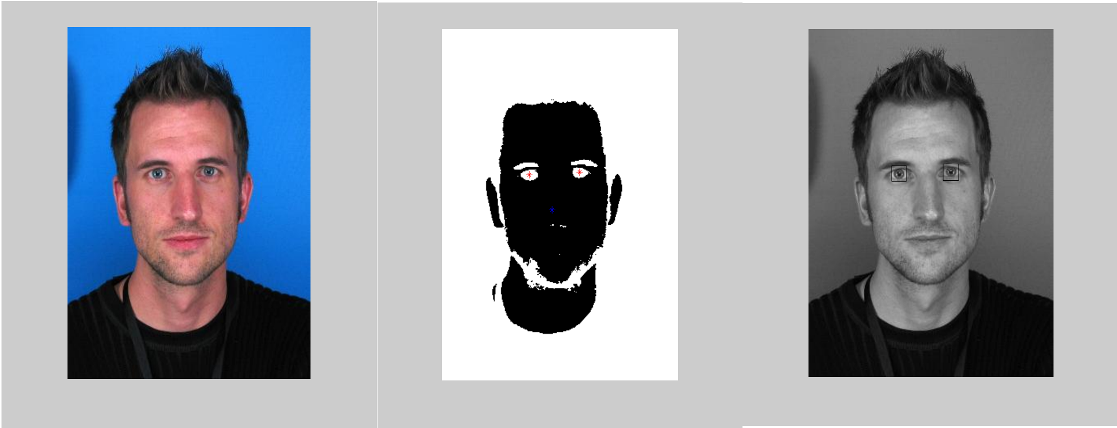


27)

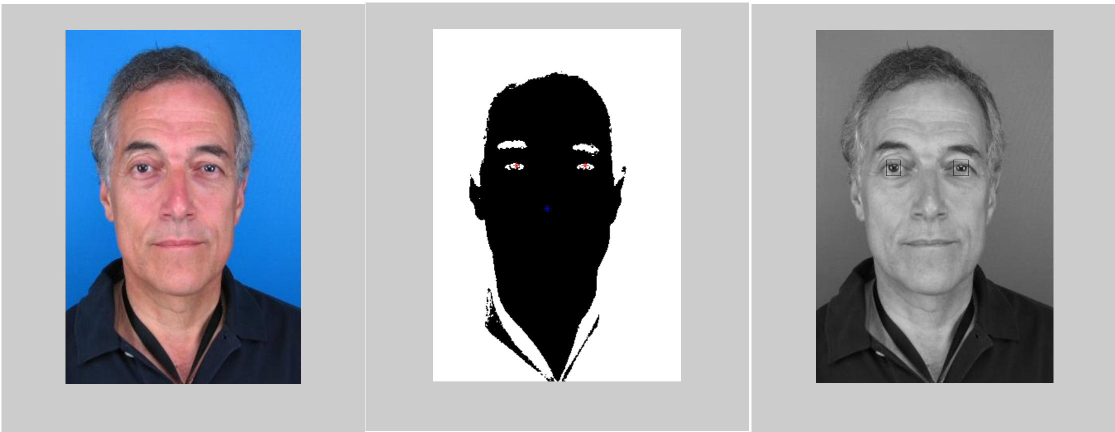


28)

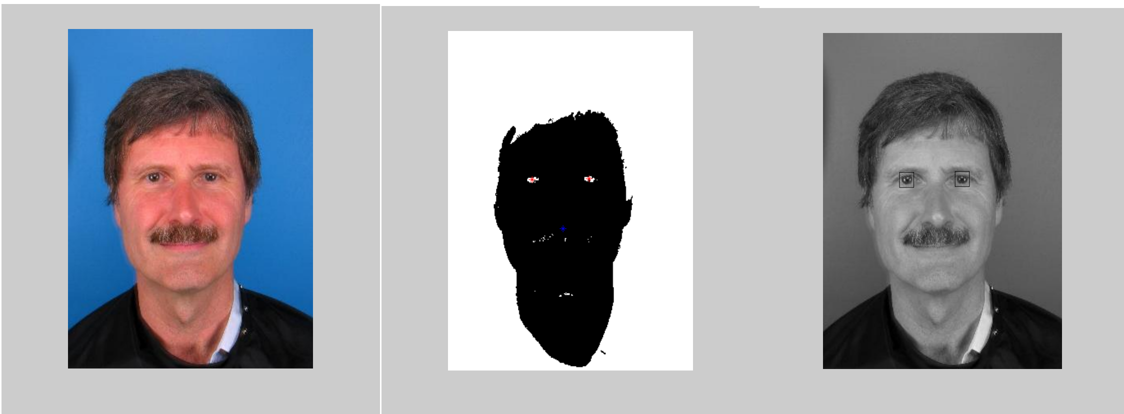
(a) (b) (c)



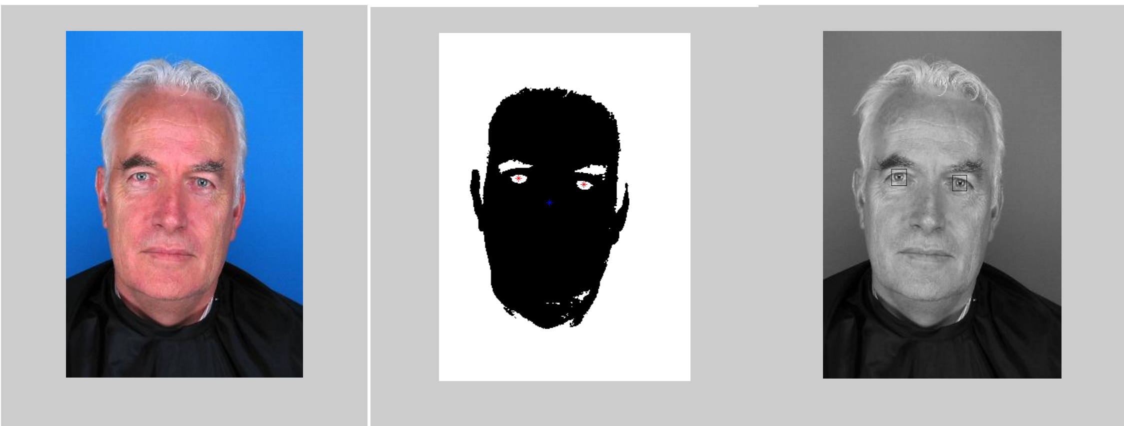
29)



30)



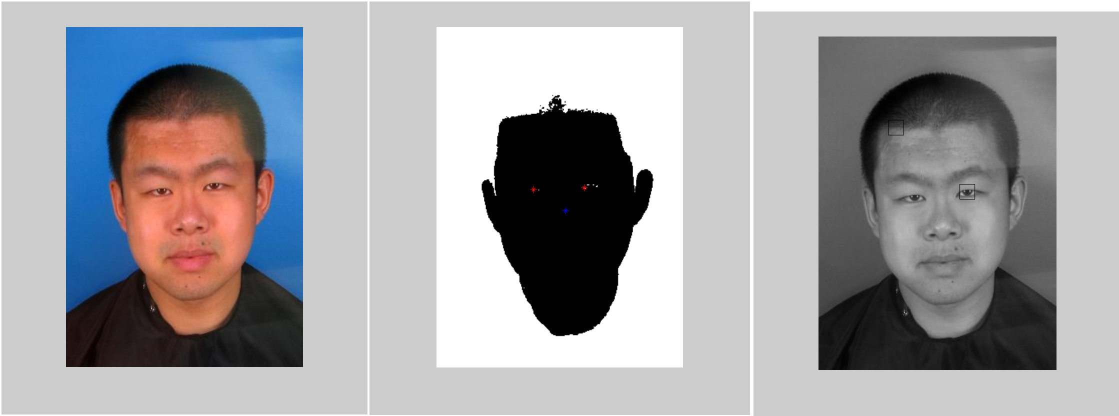
31)



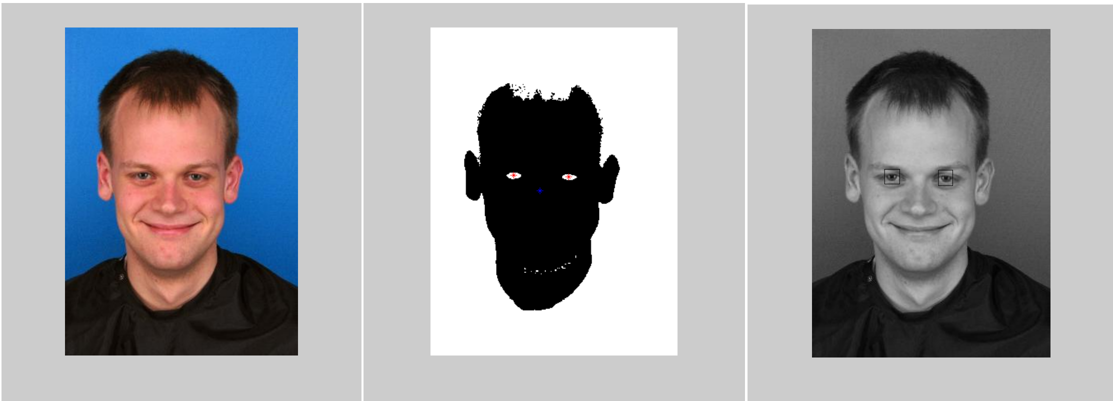
32)

(a) (b) (c)

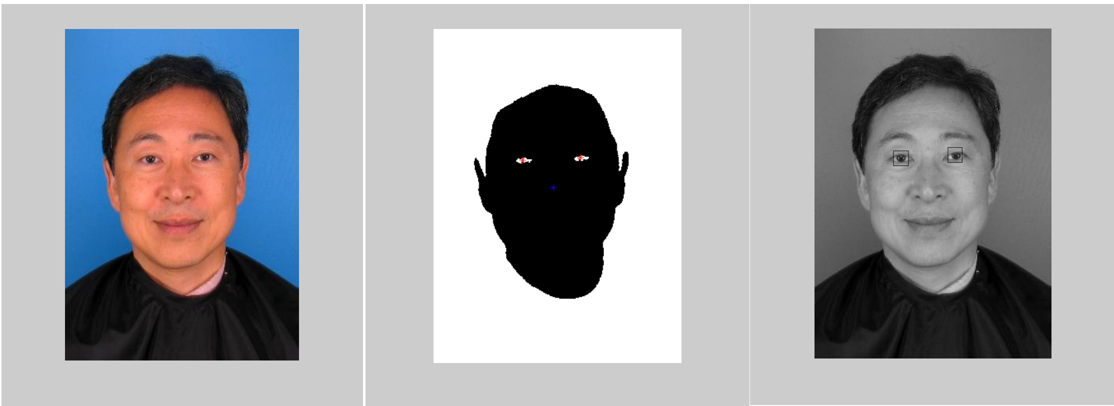
33)



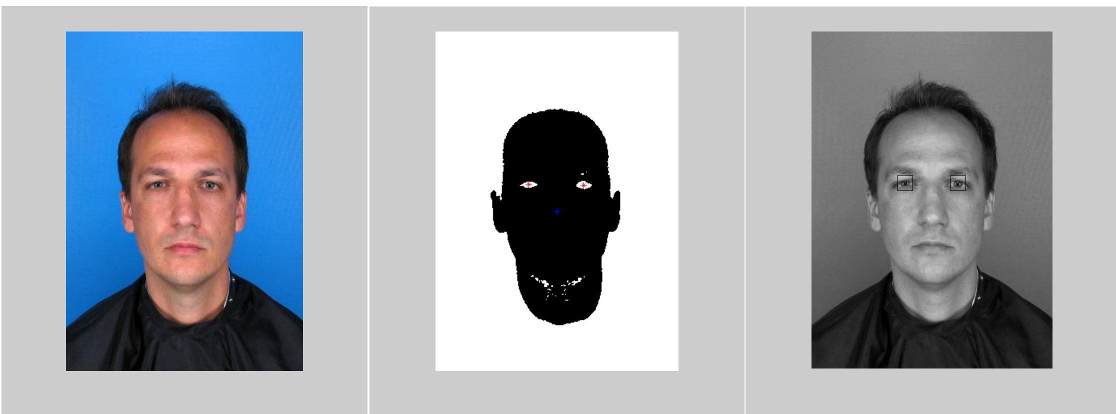
34)



35)

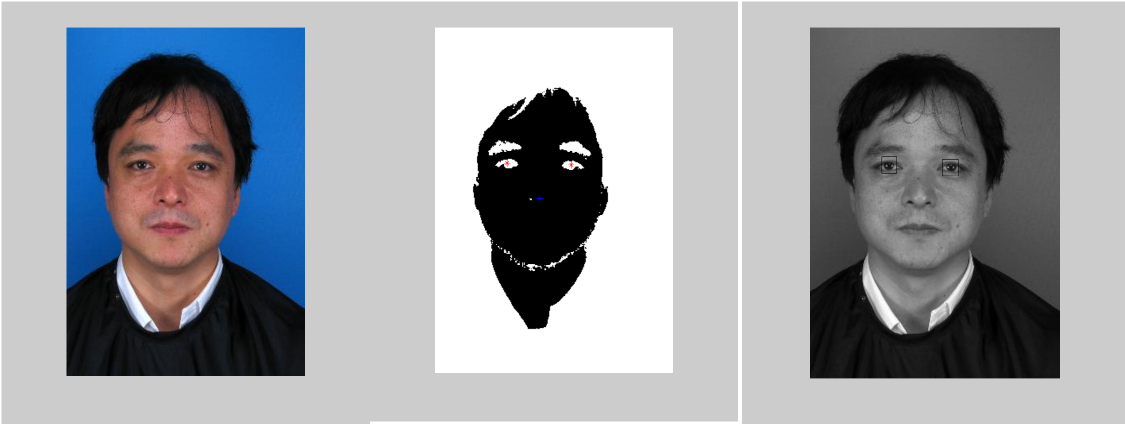


36)

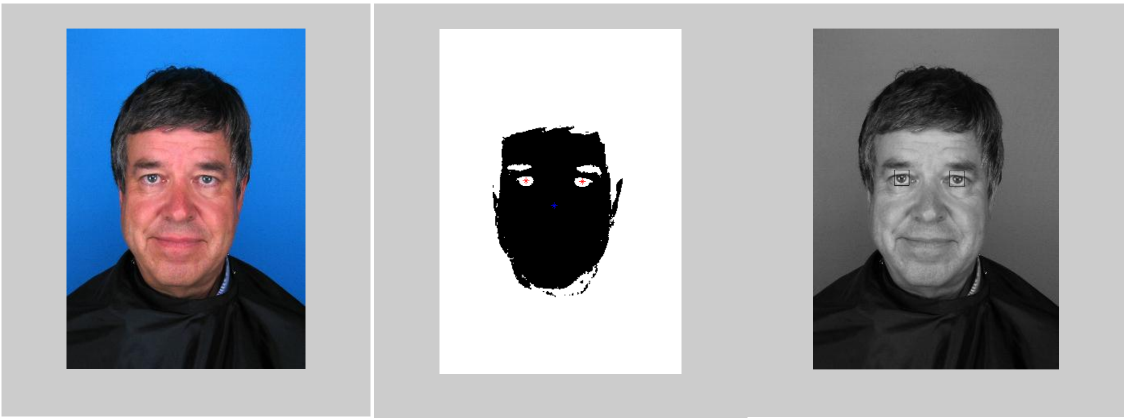


(a) (b) (c)

37)



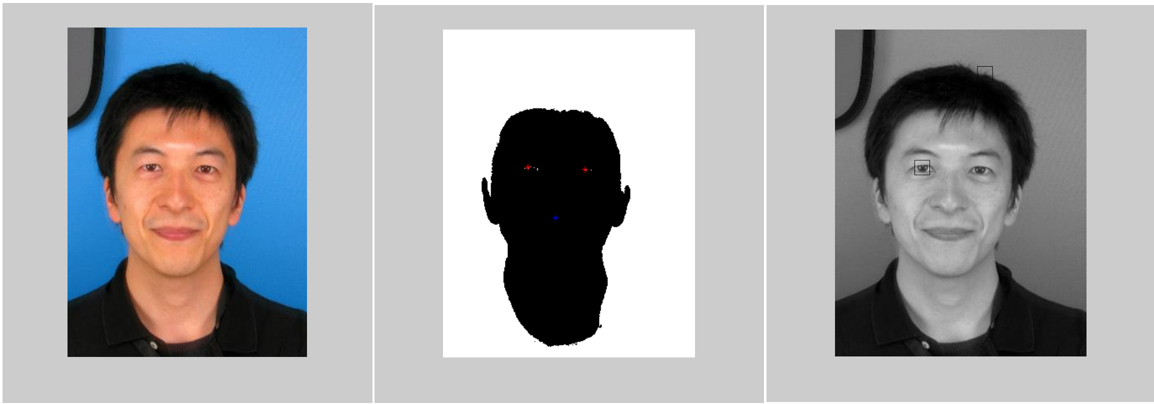
38)

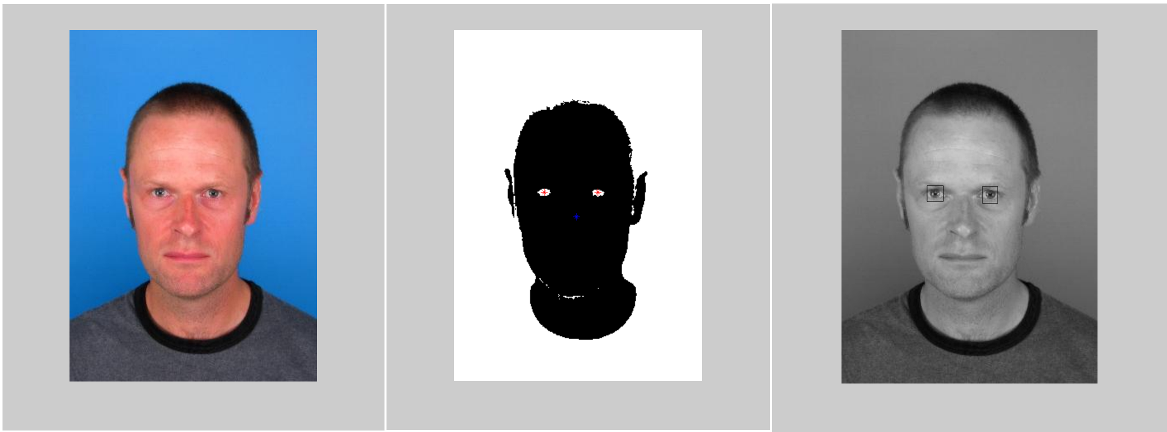


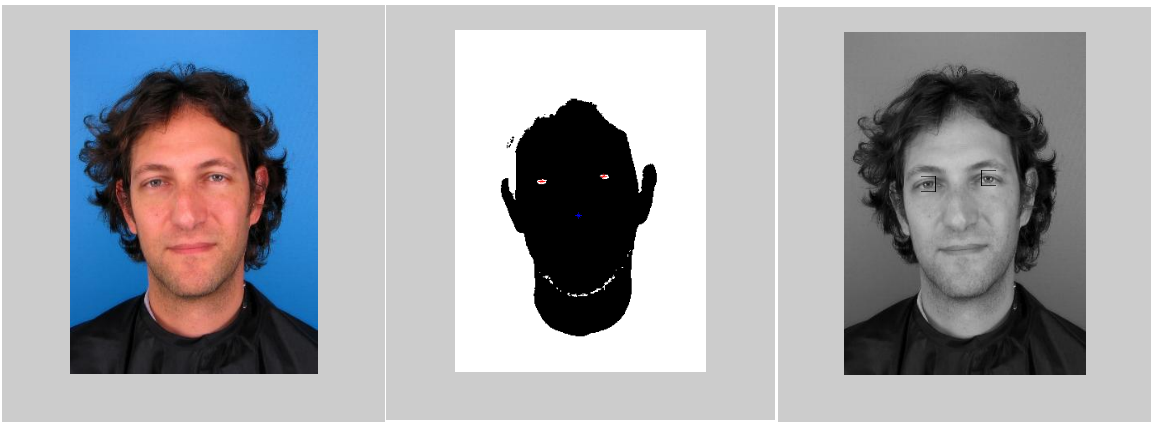
39)

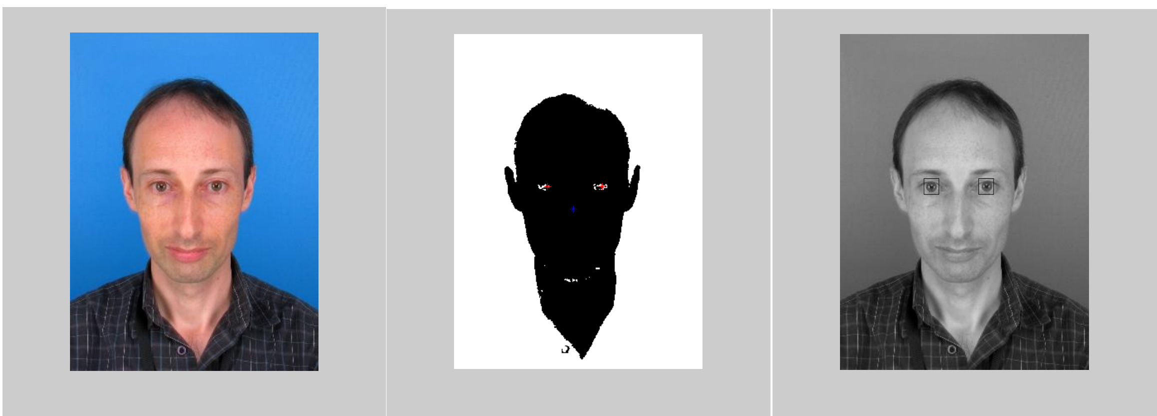
40)

(a) (b) (c)

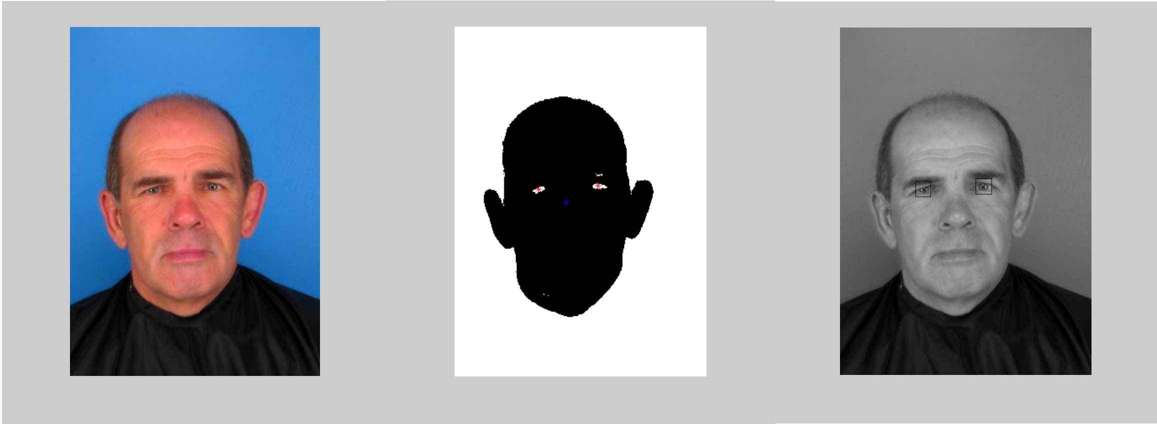
41) 

42) 

43) 

44) 

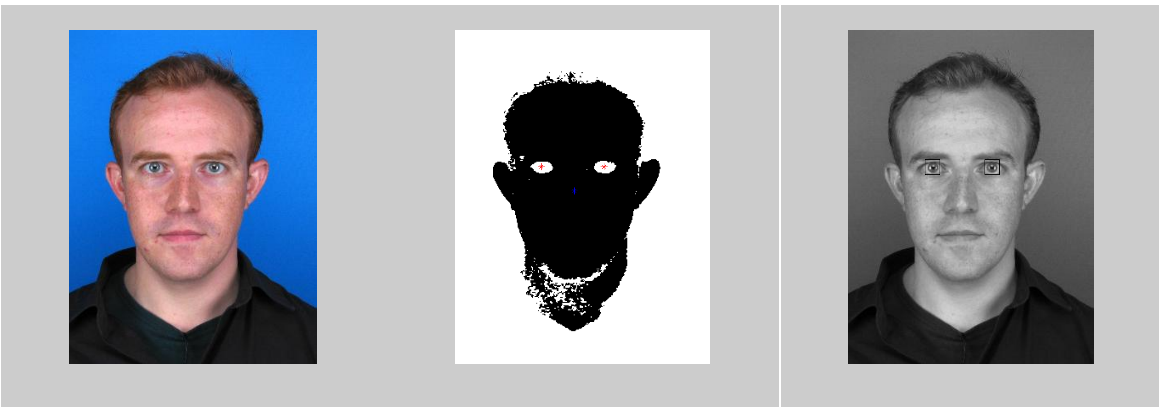
(a) (b) (c)



45)

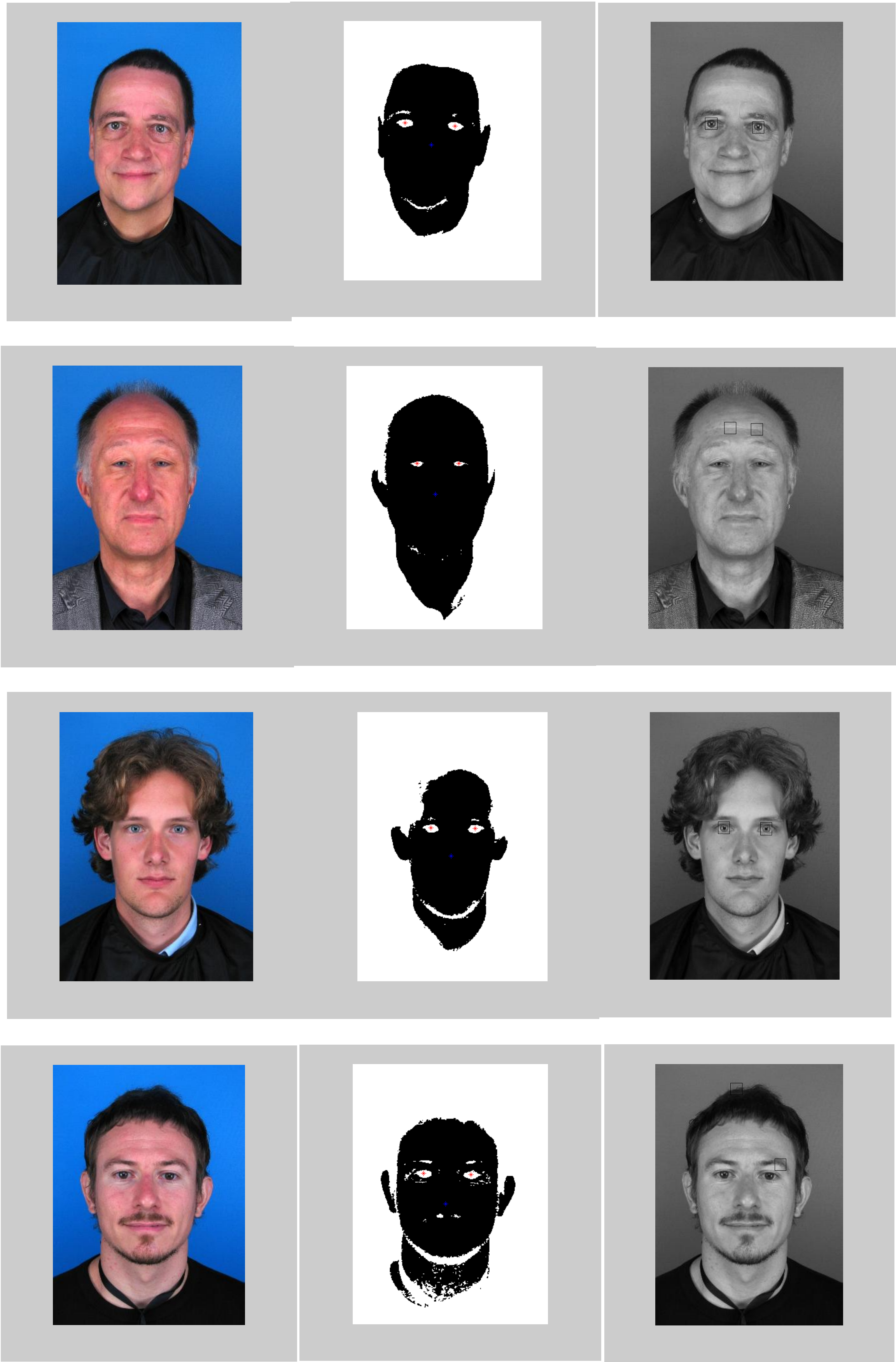
46)

47)



48)

(a) (b) (c)



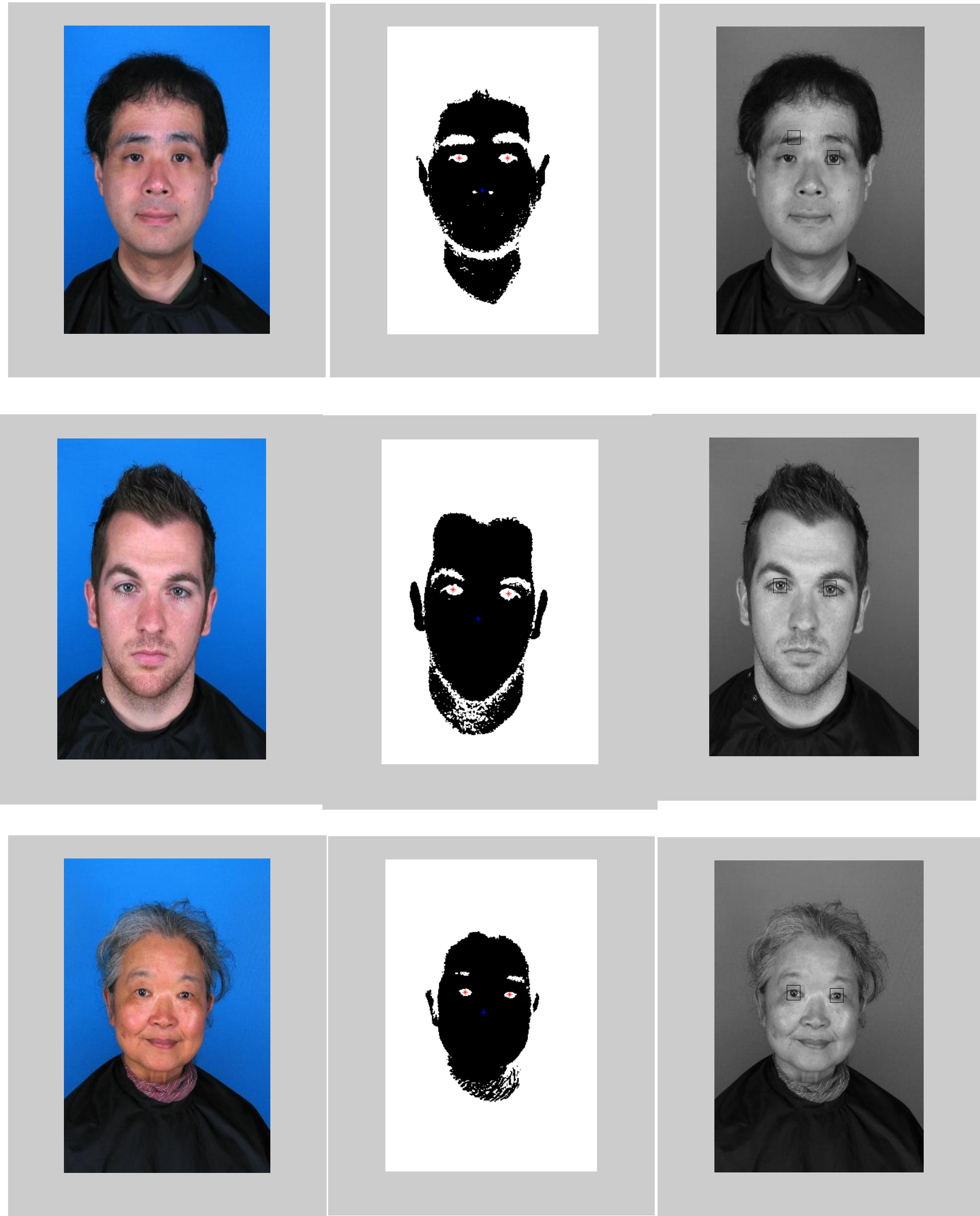
49)

50)

51)

52)

(a) (b) (c)



53) 54) 55)

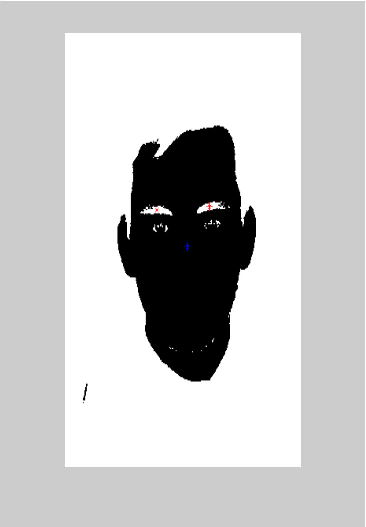
(a) (b) (c)

Fig.4.4 Results of 55 test images **(a)** Result of proposed method **(b)** Result of Eye Variance Filter

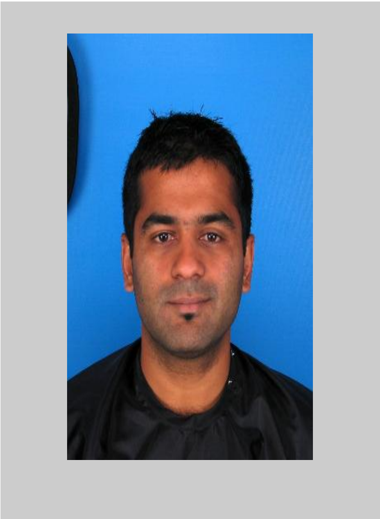
4.2 Defects of proposed method

Out of the given 55 images, the 2 images with sr. no. 9 and 24 in fig.4.3 where the eye pair is not correctly detected are shown in fig.4.5 and it is seen that instead of the eye, the eye brows are detected.

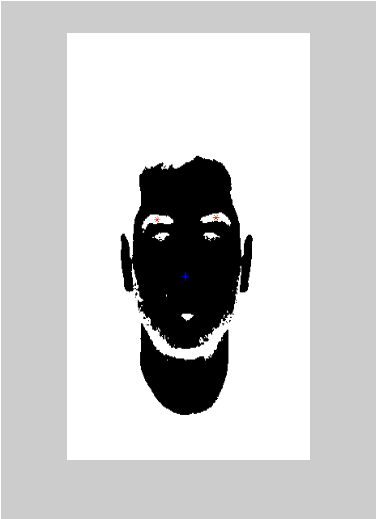
(a)



(b)



(c)



(d)

Fig.4.5 Defects of the proposed method (a)(c) original images (b)(d)wrongly detected eye pairs

4.3 Failure results of Eye Variance Filter

From the results of Eye Variance Filter it is seen that the eye detection fails in 10 images out of the given 55 images thus having accuracy of 81.81%. The images where the Eye Variance Filter failed are shown below:

Fig.4.6 Failure results of Eye Variance Filter

4.4 Results of Neural Network:

Feed forward multilayer neural network is applied to compare the results with the proposed method. The neural network is first trained with the 10 training images as shown in fig. Then the neural network consisting of 1 hidden layer with 90 hidden neurons working as processing units is used to test the given 55 test images. The results of the 55 images is given in table 4.2 given below

TABLE 4.2 Results of Neural Network on the test data

TEST IMAGES	TRUE POSITIVE	TRUE NEGATIVE	FALSE POSITIVE	FALSE NEGATIVE
1	0	5	1	1884
2	0	2	1	74
3	1	1	0	3158
4	1	7	0	695
5	0	7	1	13194
6	1	5	0	1647
7	0	1	1	5457
8	1	0	0	1175
9	1	8	0	1369
10	1	20	0	1357
11	1	24	0	1200
12	1	0	0	1128
13	1	3	0	1481
14	1	2	0	663
15	1	0	0	2774
16	1	3	0	737
17	1	11	0	9579
18	1	43	0	6742
19	1	0	0	5670
20	0	1	1	297
21	0	0	1	2554
22	0	0	1	1174
23	0	0	1	818
24	1	0	0	252
25	1	104	0	1073
26	1	0	0	90
27	1	5	0	1647
28	1	5	0	319
29	1	18	0	2984
30	0	1	1	700
31	1	3	0	1592
32	1	4	0	1270
33	1	7	0	695
34	1	0	0	1595
35	0	0	1	19
36	0	8	1	1820
37	0	17	1	3810
38	1	4	0	14775

39	1	0	0	434
40	1	8	0	46
41	1	1	0	818
42	1	1	0	2014
43	1	17	0	612
44	1	9	0	110
45	1	5	0	18522
46	0	10	1	4939
47	1	3	0	12399
48	0	0	1	859
49	0	0	1	433
50	1	4	0	775
51	1	200	0	17754
52	1	19	0	12383
53	1	66	0	20843
54	0	1	1	250
55	1	1	0	818

By analyzing the above table it seems that the results of neural network is very poor The result of neural network is hown on one dummy in fig. The eye pairs wrongly detected as eye pairs is shown in fig.4.6(a)(b)(c)(d)and the eye pair correctly detected is shown in fig 4.6(e)

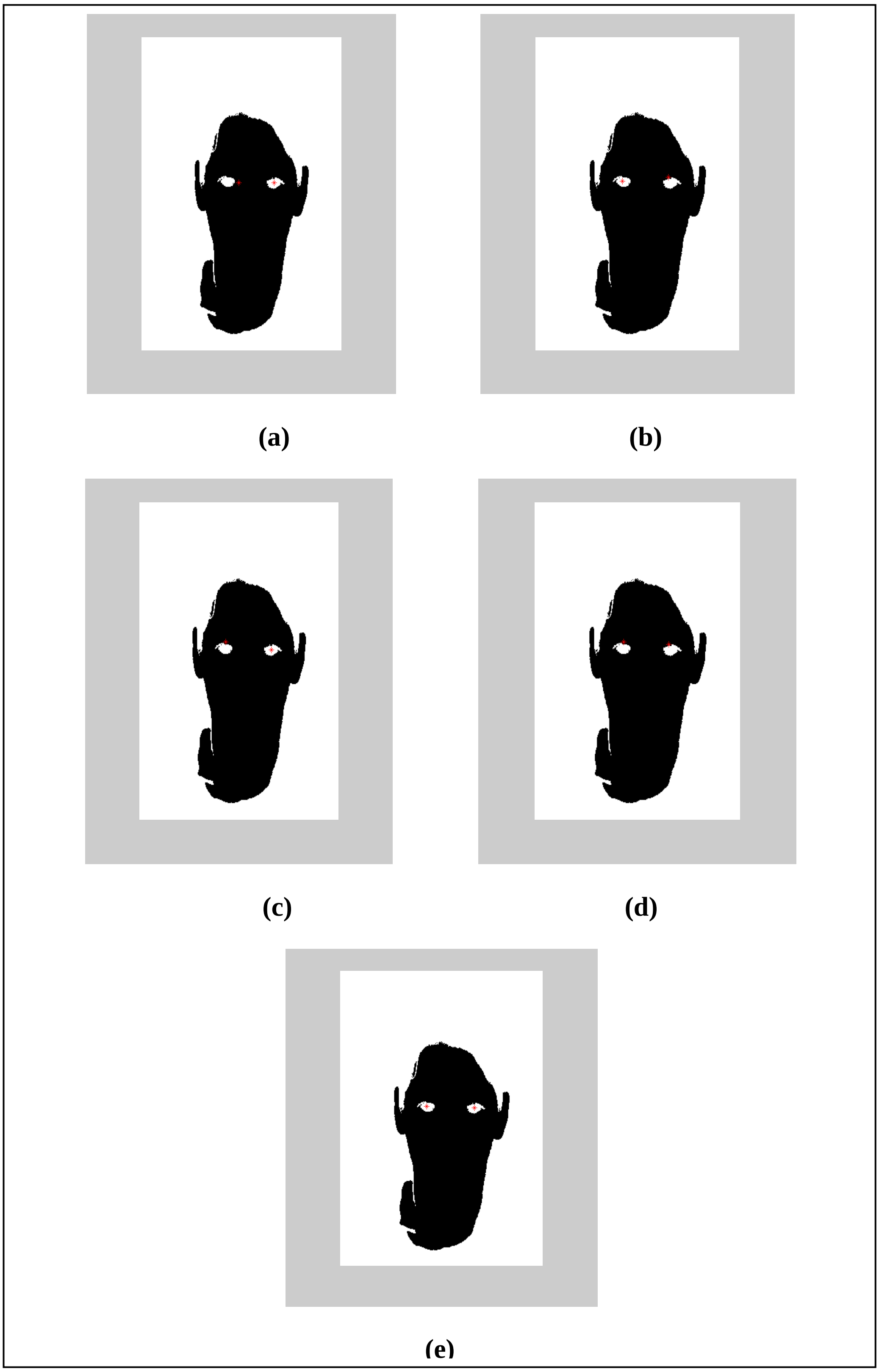


Fig. 4.6 Results of neural network (a)(b)(c)(d) non-eye pair (e) Correct eye pair

CHAPTER 5

APPLICATION TO FACE RECOGNITION

The proposed fuzzy eye detection method can be used as an application to face recognition system. For over two decades [70] face recognition has drawn attention of the research community. Face identification from a single image is a challenging task because of variable factors like alterations in scale, location, pose, facial expression, occlusion, lighting conditions and overall appearance of the face. With the synergy of efforts from researchers in diverse fields including computer engineering, mathematics, neuroscience and psychophysics, different frameworks have evolved for solving the problem of face recognition. Among these, the prominent approaches are those based on Principal Component Analysis (PCA), Local Feature Analysis (LFA), Template Matching, Neural Network, Model Matching, Partitioned Iterated Function System (PIFS), Wavelets and Discrete Cosine Transform (DCT). The choice of a particular solution is governed by its suitability in a particular application.

In PCA method, also known as Eigenface method, face images are projected onto the so called eigenspaces [71] that best encodes the variations among known facial classes, and recognition is achieved by carrying out match of these projected feature vectors.

5.1 Steps for application of proposed Eye Detection algorithm to Face Recognition

The block diagram showing the different steps involved in the face recognition by the application of the proposed eye detection algorithm is shown in Fig.5.1.

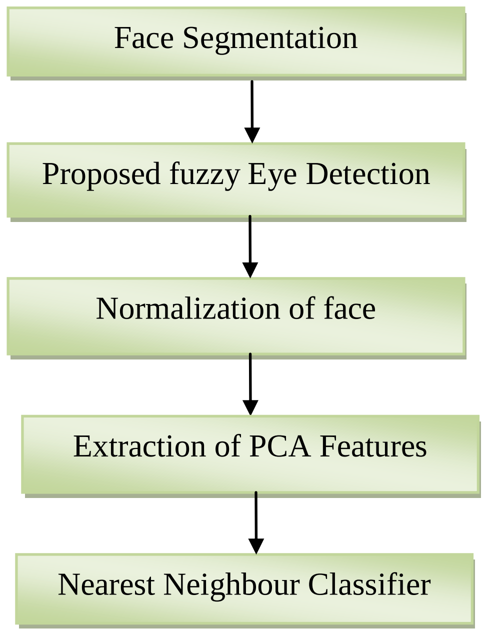
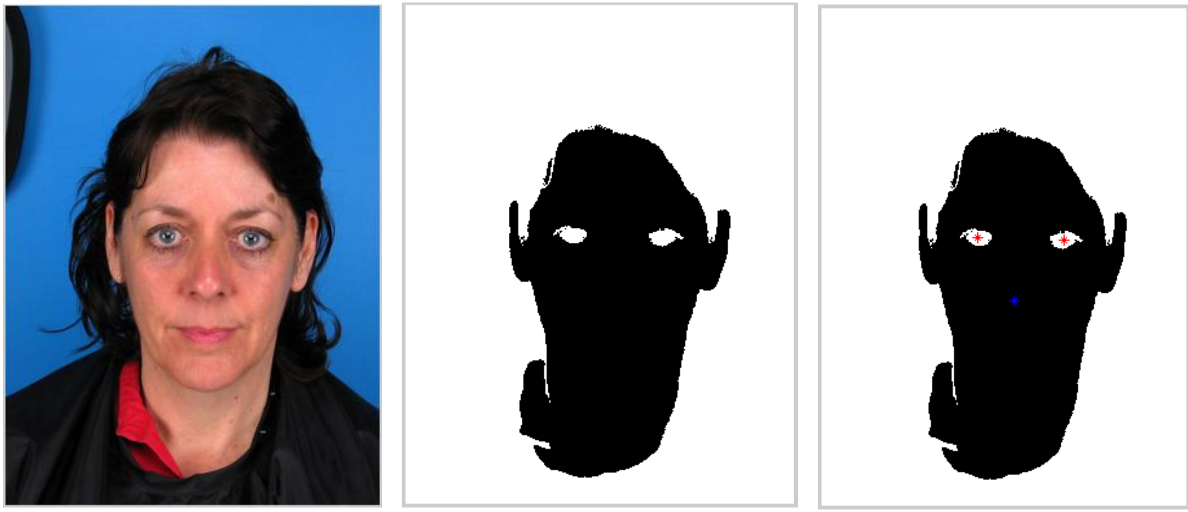


Fig. 5.1 Steps for face recognition using the proposed eye pair detection algorithm

Face Segmentation: The face segmentation process segments the skin region from the given image. Skin segmentation is done by converting the given rgb image into a color transformed image i.e. in lab model that correspond to skin color as discussed in Chapter 4,Section 4.1.

Proposed fuzzy Eye Detection: the proposed fuzzy eye detection finds the eye pair on the basis of the given eight dimensional features and their nine fuzzy memberships as discussed in Section 2.4 and 2.5.



(a) (b) (c)

Fig. 5.2 Application of proposed method on a sample image **(a)** Original Image **(b)** final Segmented image **(c)** eye pair detected

Normalization: the distance between the eye pairs is used to normalize the image. Normalization is done by first resizing the image by fixing up the distance between the eyes to 200 pixels and then cropping it as per the procedure in [57]. The final normalized image contains the cropped part of original image containing only the important and distinguishable features.

Cropping steps: The first step is to find the center point C (x_c ,y_c) of both the eyes E_1 (x_1,y_1) and E_2 (x_2,y_2) which is calculated by the following formulas:

$$x_c = \frac{(x_1 + x_2)}{2} \quad \textbf{....(5.1)}$$

$$y_c = \frac{(y_1 + y_2)}{2} \quad \textbf{....(5.2)}$$

Next step is to define a rectangle that is used to crop the face. From the center point $C(x_c, y_c)$ the top left corner $T(x_t,y_t)$ of the rectangle is obtained using formula:

$$x_t = x_c - 0.9*200 \qquad \textbf{....(5.3)}$$

$$y_t = y_c - 0.9*200 \qquad \textbf{....(5.4)}$$

the width and height of the rectangle is decided by a factor s which is given by:

$$S = 1.9 *200 \qquad \textbf{....(5.5)}$$

and the width w is taken up as S and height h of rectangle is taken as 1.5 * S. The rectangle is thus defined by the top left corner $T(x_t,y_t)$, the width w and the height h calculated by the above equations. The resized and cropped image obtained is shown in fig. 4.3(b)

(a) (b)

Fig. 5.3 (a): Measuring the distance between the detected eye pair **(b)** resized and cropped image

5.2 Extraction of PCA features

The Eigenface algorithm uses the Principal Component Analysis (PCA) for dimensionality reduction to find the vectors which best account for the distribution of face images within the entire image space [70]. These vectors define the subspace of face images and the subspace is called face space. All faces in the training set are projected onto the face space to find a set of weights that describes the contribution of each vector in the face space. To identify a test image, it requires the projection of the test image onto the face space to obtain the corresponding set of weights. By comparing the weights of the test image with the set of weights of the faces in the training set, the face in the test image can be identified.

The key procedure in PCA is based on Karhumen-Loeve transformation [71]. If the image elements are considered to be random variables, the image may be seen as a sample of a stochastic process. The Principal Component Analysis basis vectors are defined as the eigenvectors of the scatter matrix S_T ,

$$S_T = \sum_{i=1}^{N} (x_i - \mu)\,(x_i - \mu)^T \qquad \textbf{....(5.6)}$$

The transformation matrix W_{PCA} is composed of the eigenvectors corresponding to the *d* largest eigenvalues. A 2D example of PCA is demonstrated in Fig. 5.4.

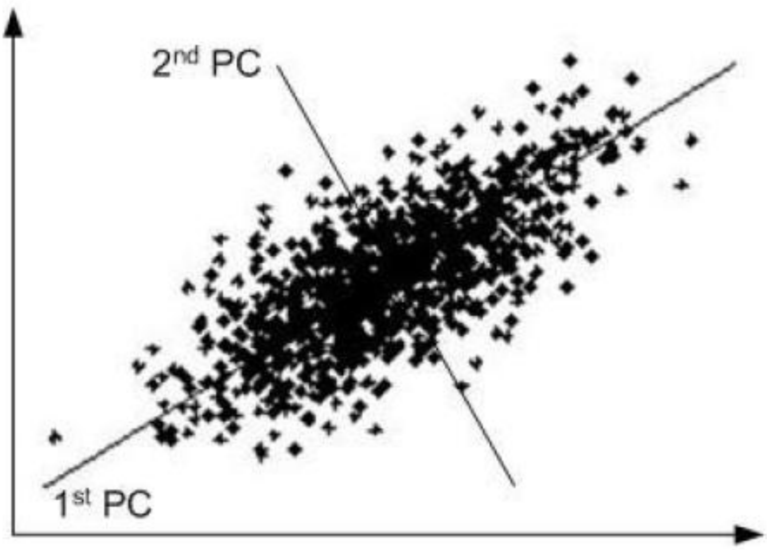


Fig. 5.4: Principal components (PC) of a two-dimensional set of points. The first principal component provides an optimal linear dimension reduction from 2D to 1D, in the sense of the mean square error

After applying the projection, the input vector (face) in an n-dimensional space is reduced to a feature vector in a d-dimensional subspace. For most applications, these eigenvectors corresponding to very small eigenvalues are considered as noise, and not taken into account during identification. Several extensions of PCA are developed, such as modular eigenspaces [73] and probabilistic subspaces [74].

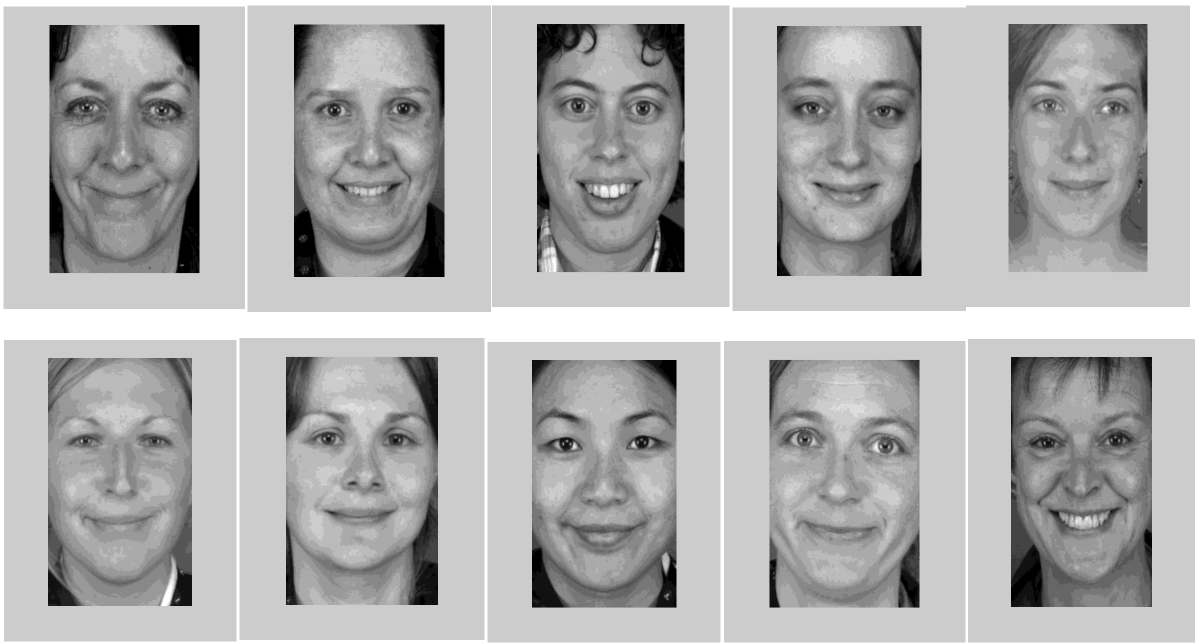
5.3 The Face Recognition experiment

We took 10 random images from the database and extracted PCA features for classification using nearest neighbour classifier for the following 2 cases

1) Without eye detection and normalization
2) With eye detection and normalization by proposed technique

(a)

(b)



(c)

Fig. 5.4 (a) ten original images (training images) **(b)** ten test images **(c)** Cropped images after the proposed eye detection

It is seen from table 5.1 and Fig 5.4 that when the PCA features of the original images are subjected to the nearest neighbour classifier, 8 images out of 10 are classified thus giving an accuracy of 80% where as by using the proposed eye detection method and normalizing on the basis of it the recognition rate is 100% i.e. all 10 images are classified correctly.

Table 5.1: Face recognition results using proposed method and without using proposed method for normalization.

Recognition rate without proposed eye detection and normalization	**Recognition rate with proposed eye detection and normalization**
80%	**100%**

CHAPTER 6

CONCLUSION AND FUTURE WORK

Conclusion:

A robust eye detection method is reported in this thesis. The presented algorithm integrates some of the techniques used by image processing systems to detect the human face and to locate its salient features. By using the proposed facial features and their Gaussian memberships correct eye pairs can be detected. The distance between the eyes can then be used for normalizing and cropping the image to extract only distinguishable features for application to face recognition system. The experimental results show a correct eye detection rate of 96.36% by the proposed method. Moreover using the proposed method for face recognition system improves the recognition rate to 100% while it is 80% without using this method. Thus it can be concluded that

- The proposed eye detection algorithm has a detection time suitable for use in automated face recognition systems.
- The proposed method works even if the eyes are closed.
- Given any training dataset the proposed method can correctly detect the eye pair in an image.
- The low complexity of the design and the low cost of implementation of the system make this technique a very feasible one for practical purposes.
- The efficiency achieved by the proposed fuzzy eye detection is more than all the other techniques that are commonly used.
- The space and time complexity of the proposed algorithm are lesser than the space and time complexity of the existing technology for speaker recognition.

Future work

Based on our face and facial features detection method, much more works can be done in the future. The proposed work uses frontal face images; we can further work on different orientation of the face. Improvement can be done in the face segmentation part since there are a lot many constraints while detecting the skin regions. The human skin can be close to the clothes he/she might be wearing and thus further work to improve the skin detection part can be done. The proposed method does not perform well under the following situations:

- Parts of the eyes are covered by hair.
- When the face with spectacles is given as input

We will try to improvise the performance of our system for such shortcomings in our future work.

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