Chapter-3

IRIS SEGMENTATION

This chapter summarizes the most common iris segmentation methods and discusses their robustness when dealing with noisy images. Based on this, a more robust iris segmentation method for noisy images is proposed. It also discusses various steps as pre-processing, segmentation and normalization. In this chapter, Integro-differential operator, Hough transform, Geodesic active contour method and Canny edge detection algorithm are explained. The results obtained after implementation, comparison and analysis of these segmentation methods using performance parameters are discussed in this chapter.

3.1 Introduction

Iris segmentation plays a key role in the performance of an iris recognition system. This is because improper segmentation can lead to incorrect feature extraction from less discriminative regions (e.g., sclera, eyelids, eyelashes, pupil, etc.), thereby reducing the recognition performance.

The work in this thesis addresses the issue of iris image segmentation for an improved texture extraction, as it is reported that most match failures in iris recognition system result from inaccurate iris segmentation. However, iris segmentation is the most time consuming step in the iris recognition system and so become the bottleneck in real time environments. Iris segmentation is difficult task and faces some challenges such as specular reflection, contrast enhancement, blurred images and occlusion.

In this chapter, for performing iris segmentation in challenging conditions, Integro-differential operator, Hough transform, Active contours and Canny edge detector techniques are considered. The first two curve fitting techniques are classical approaches that are computationally inexpensive. The two newly proposed techniques ensure a good combination between contour fitting and curve evolution based approaches for performing iris segmentation in a challenging database.

3.2 Challenges in Iris Segmentation

Iris segmentation refers to the process of automatically detecting the pupillary (inner) and limbic (outer) boundaries of an iris in a given image. This process helps in extracting features from the discriminative texture of the iris, while excluding the surrounding regions. Segmentation of an iris image is a classical image processing problem. Processing non-ideal iris images is a challenging task because of following reasons:

- The iris is often partially occluded by eyelids, eyelashes, and shadows.
- The iris is sometimes occluded by specular reflection.
- The iris and the pupil are noncircular, and the shape varies depending on how the image is captured.
- Some of the other challenges of iris segmentation are defocusing, motion blur, poor contrast etc. These challenges are taken care by measuring the quality of input iris image and then continue with segmentation of the good quality image only.
- The noise in images is considered to be of these types- the iris obstruction by eyelids or eyelashes, specular or lighting reflections, poor focused image, partial or out-of iris image, motion blurred as belonging to the iris.

Two main challenges of iris segmentation of realistic eye images are addressed: segmentation accuracy and processing speed.

The first proposed method is to improve the iris segmentation accuracy by using Geodesic Active Contours at the expense of higher computational complexity. The second proposed method is based on Canny edge detector and is primarily aiming for the faster iris segmentation of more noisy database like UBIRIS database with sufficient segmentation accuracy as compared to earlier reported work.

3.3 Existing iris segmentation methods

A significant number of iris segmentation techniques have been proposed in the literature. Two most popular techniques are based on using an integro-differential operator and the Hough transform, respectively. The performance of an iris segmentation technique is greatly dependent on its ability to precisely isolate the iris from the other parts of the eye. Both the above listed techniques rely on curve fitting approach on the edges in the image. Such an approach works well with good quality, sharply focused iris images. However, under challenging conditions (e.g., non-uniform illumination, motion blur, off-angle, etc.), the edge information may not be reliable. Table 3.1 summarizes the different algorithms for iris segmentation proposed by various researchers.

Table 3.1: Overview of prominent existing methods of iris segmentation

Author	**Iris segmentation techniques used**
Daugman *et al.* [14]	Integro-differential operator
Wildes *et al.* [23]	Image intensity gradient and Hough transform
Ma *et al.* [34]	Hough transform
Ma *et al.* [35]	Gray level information, canny edge detection, and Hough transform
Masek [98]	Canny edge detection, and Hough transform
Abhyankar *et al.* [55]	Active shape model
Basit & Javed *et al.*[99]	Maximization of the difference of intensities of radial direction
M. Vatsa *et al.*[30]	Modified Mumford–Shah functional
K. Nguyen *et al.*[103]	Shrinking and expanding active contour methods

The best known and thoroughly examined iris segmentation method is Daugman *et.al.*[17] method using Integro differential operators, which are a variant of the Hough Transform, act as circular edge detectors and have been used to determine the inner and the outer boundaries of the iris. They also have been used to determine the elliptical boundaries of the lower and the upper eyelids.

The Hough transform is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image. The circular Hough transform can be employed to deduce the radius and centre coordinates of the pupil and iris regions. Firstly, an edge map is generated by calculating the first derivatives of intensity values in an eye image and then thresholding the result. From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point.

The Hough transform and its variants were employed by authors B.Chouhan *et al.* [93], H. Proenca *et al.* [78], Liu *et al.* [58][86], Ma *et al.* [34][35] , Masek [98],Wildes [23] for iris segmentation.

3.4 Typical Iris Recognition System

Figure 3.1 shows the block diagram of typical iris recognition system used for the performance evaluation. The main focus is on iris segmentation and feature extraction method. For the comparison of proposed different segmentation algorithms, all other modules in the recognition system are kept same and the performance of recognition is analyzed by changing the segmentation method. Many open access databases are available for the research use. The databases used for evaluating performance of iris recognition system here are CASIA Interval version 3 database and UBIRIS database.

3.4.1 Pre-processing :

Pre-processing of the acquired iris image involves detection of specular reflections and this stage must remove these noise elements that can affect the feature extraction process. 2-D median filtering and in-painting is used here, if specular reflections in the image are present.

3.4.2 Segmentation :

Two methods are proposed during this work as Geodesic Active Contours without edges and Canny edge detector method. Also, segmentation performance is compared with the earlier reported work with Integro-Differential Operator and Hough transform.

3.4.3 Normalization :

Iris segmentation is followed by a normalization to generate fixed dimension feature vectors further to be used for recognition by comparisons. The rubber sheet model proposed by Daugman maps each point in the (x, y) domain to a pair of polar coordinates (r, θ). This results in a fixed size unwrapped rectangular iris image.

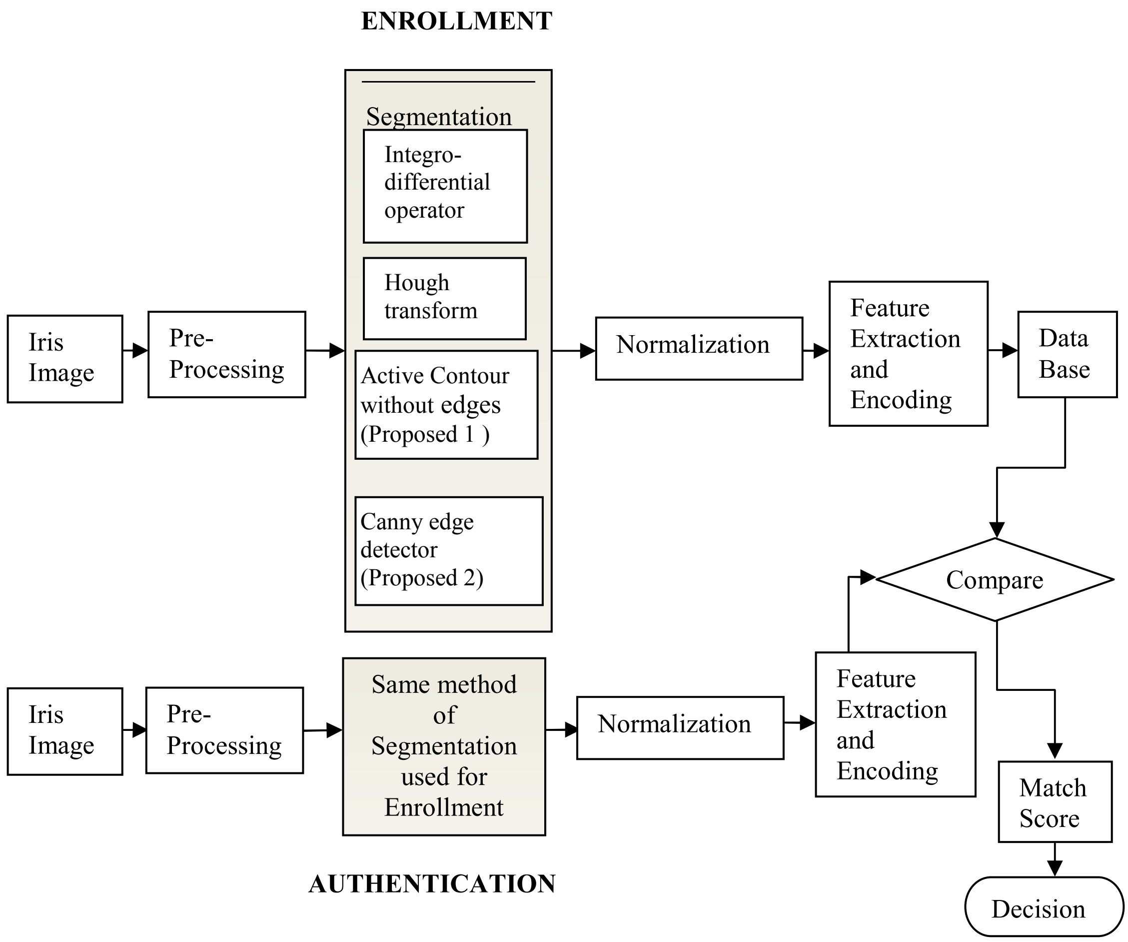


Fig.(3.1) : Block diagram of Iris Recognition system

3.4.4 Feature Encoding and Matching :

For accurate recognition result, the most discriminating information present in an iris pattern must be extracted. Only the significant features of the iris must be encoded so that comparisons between irises can be made. In order to study the effects of iris segmentation on the iris recognition accuracy performance Log Gabor filters are used to extract the textural information (encoding) from the unwrapped iris. Further, the feature vectors are compared using a similarity measure for which matching algorithm is used.

3.5 Iris Databases

Different iris databases of different universities / institutes have been used for testing the proposed methods. Two databases of Chinese Academy of Sciences, Institute of Automation (CASIA) Iris Database Version 1.0 and 3.0 [9], one from University of Bath (BATH), UK [10], University of Beria Interior (UBIRIS)[75] and one from Multi Media University (MMU), Malaysia [11] have been used for evaluation. Table 3.2 shows some of the attributes such as file format, number of classes and dimension.

Table 3.2: Some attributes of the Iris Databases

Sr. No.	**Name of Database**	**File format**	**Number of images**	**Number of classes**	**Number of images in each class**	**Dimension of image in pixels**
1.	CASIA Version 1.0	BMP	756	108	7	280X320
2.	CASIA Version 3.0	JPG	2655	396	1-26	280X320
3.	Bath	BMP	1000	50	20	960X1280
4.	MMU Version 1.0	BMP	450	90	5	240X320X3
5.	UBIRIS	TIFF	1877	241	1-9	800X600

As the acquiring device as well as environment is not unique for all databases, therefore, different types of pupil images are present in the databases. Figure 3.2 is set of sample images taken from UBIRIS database, which contains the combination of poorly focussed, good, occluded, Motion blurred and light reflected images.

Analysis of the noise factors and the image heterogeneity has been considered as the most important parameters. Various noise factors in iris images considered are: Iris obstructions by eyelids and eyelashes, Lighting reflections, specular reflections, Poor focused images, Off-angle iris and Motion blurred images. Each database considered here is having such images in the respective dataset.

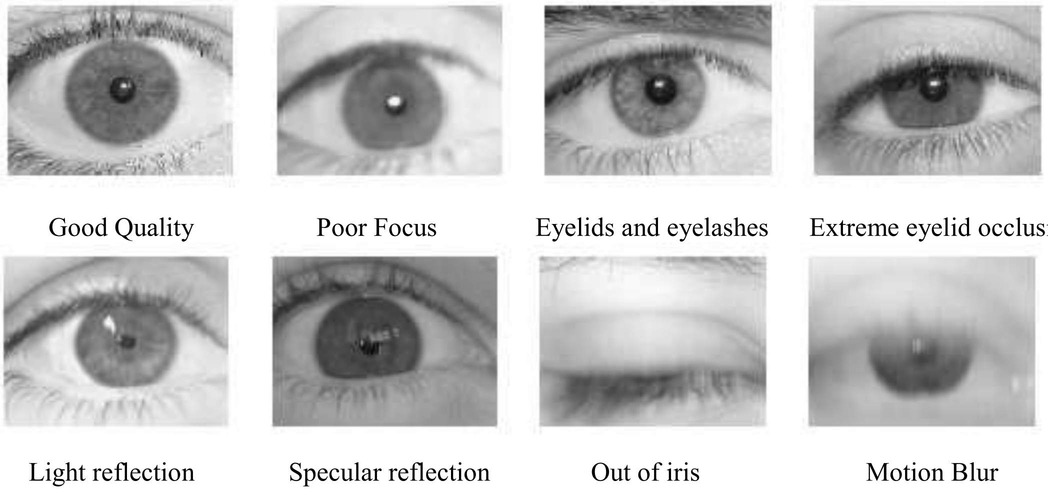


Fig. (3.2): Sample images from the UBIRIS database

As can be seen from the Table 3.3 the UBIRIS and CASIA are the two databases with the highest amount of noise present. So, for the further study we decide to use these databases for studying the performance of the proposed segmentation algorithms.

Table 3.3: Average quantity of noise pixels within the iris

Iris Database	Image Size	Noise, %
BATH	1280 × 960	6.29
CASIA	320 × 280	12.72
MMU	320 × 240	7.83
UBIRIS	800 × 600	27.62

The analysis of the database allowed us to conclude that the noisiest database is the UBIRIS database. All the remaining databases contain less number of noisy images and their images have more homogeneous characteristics. After the identification of the types of noise that each available database contains, it prompted to have an objective measure in terms of average quantity of noisy pixels per iris image in each database [79].

3.6 Pre-processing of Iris Image

Processing of the acquired iris image involves detection of specular reflections and this stage must remove noise and elements that can affect the feature extraction process. The features extracted must not be corrupted. The different operations used for preprocessing are image binarization (threshold), histogram equalization, inpainting, morphology operators and 2-D median filtering.

Iris images of CASIA-Iris-Interval were captured with their self-developed close-up camera with circular NIR LED array. Because of this there are six specular reflection points in the iris image. Due to the specular reflections the pupil segmentation gets affected which results in the under segmentation. Hence, if specular reflection (bright spots in an image) is detected in the surrounding area of the pupil, it is "*in painted*" using the surrounding information. Figure 3.3 shows the images before and after the specular reflection removal and inpainting. Inpainting is a process to fill the missing portions of an image (in our case specular reflections) to improve its integrity.

(a) (b)

Fig. (3.3) : (a) Original Image (b) Image after Preprocessing
(S1011L07 from CASIA interval version 3 database)

3.7 Iris Segmentation Using Different Methods

Each algorithm of iris recognition system begins with iris segmentation. Following important steps are involved in ris segmentation methods.

1. Finding the pupillary boundary of the iris
2. Finding the limbic boundary

3. Specular reflection removal, if any
4. Detecting and removing any superimposed occlusions of eyelashes, shadows or reflections.

It is reported that most failures to match in iris recognition system result from inaccurate iris segmentation. For instance, even an effective feature extraction method would not be able to obtain useful information from an iris image that is not segmented accurately. So for the better performance of the iris recognition system correct segmentation method plays vital role.

We have also implemented the iris segmentation methods using Integro-Differential Operator and Hough transform by using freely available MATLAB code with appropriate modifications for images of CASIA-interval-V3and UBIRIS databases.

3.7.1 Integro Differential operator :

John Daugman developed the fundamental iris algorithm for recognition system. The best known and thoroughly examined iris segmentation method is Daugman *et.al.*[13] method using Integro differential operators, which are a variant of the Hough Transform, act as circular edge detectors and have been used to determine the inner and the outer boundaries of the iris. They also have been used to determine the elliptical boundaries of the lower and the upper eyelids. An Integro differential operator can be defined as:

$$\max_{(r,x_0,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,\ y)}{2\pi r} ds \right| \tag{3.1}$$

where, I(x, y) is the image, the operator search over the image domain I(x, y) for the maximum in the blurred derivative with respect to increasing radius r, of the normalized contour integral of I(x, y) along a circular arc ds of radius r and centre (x_0 ,y_0). The symbol * denotes convolution and G(r) is a Gaussian filter used as a smoothing function. It is obvious that the results are inner and outer boundaries of iris. First, the inner boundary is localized, due to the significant contrast between iris and pupil regions. Then, outer boundary is detected; using the same operator with different radius and parameters. The eyelids can be detected in a similar fashion by performing the integration over an elliptical boundary rather than a circular one [31]. The output of segmentation using integro-differential operator is shown in the figure 3.4.

- **Algorithm used for Implementation of Integrodifferntial operator**:

Step 1: Initialize rmin=95, rmax=105 & scaling=0.25.

Step 2: Coarse search for iris center.

Step 3: Perform line integration.

Step 4: Carry out the differentiation.

Step 5: Obtained the blurred image using Gaussian filter.

Step 6: Determine the maximum value of blurred image for the coarse center coordinates and radius.

Step 7: Implement equation, $\max_{(r,x_0,y_0)}\left|G_\sigma(r) * \frac{\partial}{\partial r}\oint_{r,x_0,y_0}\frac{I(x,\ y)}{2\pi\pi}ds\right|$

Step 8: Fine search around this roughly located center.

Step 9: Initialize rmin and rmax for pupil

Step 10: Repeat step 3 to step 6.

Step 11: Draw the circle using iris center and radius.

Step 12: Draw the circle using pupil center and radius.

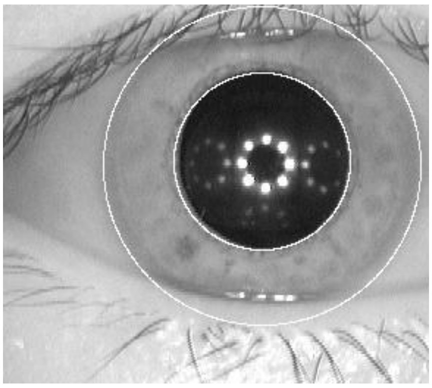


Fig. (3.4) : Segmentation output using Integrodifferential operator of image from CASIA interval version 3 database

3.7.2 Hough Transform :

The Hough transform is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image. The circular Hough transform can be employed to deduce the radius and centre coordinates of the pupil and iris regions. Firstly, an edge map is generated by calculating the first derivatives of intensity values in an eye image and then thresholding the result. From the edge map, votes are cast in Hough space for the parameters of circles passing through each edge point. These parameters are the centre coordinates x_c and y_c, and the radius r, which are able to define any circle according to the equation (3.2),

$$x_c^2 + y_c^2 - r^2 = 0 \qquad (3.2)$$

A maximum point in the Hough space will correspond to the radius and centre coordinates of the circle best defined by the edge points. This involves first employing canny edge detection to generate an edge map. Gradients were biased in the vertical direction for the outer iris/sclera boundary, as suggested by Wildes *et al.* [23]. Vertical and horizontal gradients were weighted equally for the inner iris/pupil boundary. A modified version of Canny edge detection (MATLAB function) is implemented, which allowed for weighting of the gradients. The range of radius values to look for is set manually, based on the database used. For the CASIA V1database, values of the iris radius range from 90 to 150 pixels, while the pupil radius ranges from 28 to 75 pixels. For more efficient and accurate circle detection process, the Hough transform for the iris/sclera boundary is performed first, then the Hough transform for the iris/pupil boundary was performed within the iris region, instead of the whole eye region, as the pupil is always inside the iris region.

After the completion of this procedure, six parameters; the radius, and x and y centre coordinates for both circles are saved. Canny edge detection is used to create an edge map, and only horizontal gradient information is used. The segmentation iris image using Hough Transform is shown in the figure 3.5.

- **Algorithm for Hough transform (Masek method) Segmentation**:

Step 1: Initialize pupil radius =28 and iris radius =75 for CASIA database.
Step 2: Scale the image.
Step 3: Gaussian filtering.
Step 4: Edge map creation using canny edge detection.

Step 5: Circular Hough transform for limbic boundary detection

Step 6: Circular Hough transform for pupillary boundary detection inside located iris.

Step 7: Linear Hough transform for eyelid detection.

Step 8: Display the segmented image.

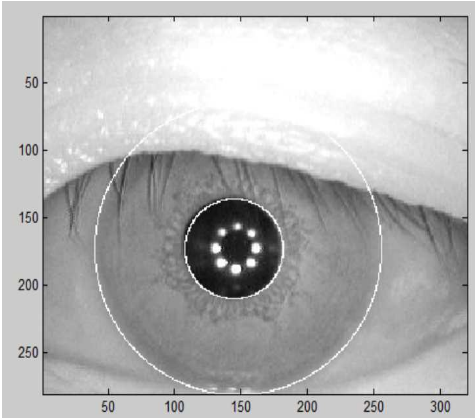


Fig. (3.5) : Segmentation output using Hough transform of image S1011L07 from CASIA interval version 3 databases

3.8 Proposed Method 1:

Accurate iris segmentation using Geodesic Active Contour (GAC)

The active contour models or snake is defined as an energy-minimizing spline- the snakes energy depends upon its shape and location within image. Local minima of this energy then correspond to desired image properties. Active contour models may be used in image segmentation and understanding.

There are two main groups of deformable contour/surface models: active contour/ snakes belong to parametric model family as borders are represented in parametric form. The second family of deformable surfaces-geometric deformable models-overcome the problems with snakes by representing developing surfaces by partial differential equations. The main feature separating geometric deformable models from parametric ones is that the curves are evolved using only geometric computations, independent of any parameterization: the process is implicit [32].

This approach is based on the relation between active contours and the computation of geodesics (minimal length curves). The technique is to evolve the

3.9 Proposed Method 2: Fast Iris Recognition Using Canny Edge Detector

Daugman [15] uses integro differential operator for locating the circular iris and pupil regions, and then arcs of the upper and lower eyelids. However, the algorithm fails when there is noise in the iris image, such as reflections, since it works well only on a local scale. Wildes [20] is based on the contour fitting approach using the circular Hough transform for the parameters of circles passing through each edge point using 'brute-force' approach. This approach is used by many researchers due to its better accuracy.

This method has two major difficulties despite of good segmentation accuracy. In case of the realistic images such as UBIRIS database the intensity variation is not same across the whole image. It is difficult to decide the single threshold for iris segmentation for both iris and pupil detection both at a time to produce edge map of outer and inner boundary. So, minimum two iterations need to be carried, first for outer boundary and then for the inner boundary. Due to this the computational complexity of the implementation is very high.

In the proposed approach, to overcome these problems, canny edge detector [89] uses two thresholds, unlike other edge detectors and Hough transform, that to for detection of outer boundary only. Inner boundary is detected by thresholding the images and detecting the edge by analyzing connected region. Figure 3.27 shows a flowchart of the proposed iris recognition algorithm with its major processing steps.

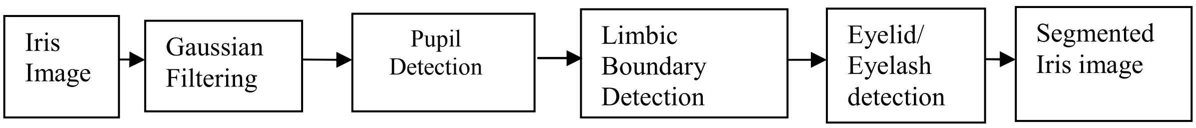


Fig. (3.27) : Flowchart of proposed Iris segmentation system

3.9.1 Inner Boundary (Pupil) Location :

The module of the pupil detection has been designed to localize pupillary boundaries. The module is responsible for the following four processing steps. In the present work, pupil is assumed to having circular shape. Thus, pupil detection consists of localization of the Centre of the pupil circle and estimation of the radius of the circular pupillary boundaries. The sub regions in the pupil area where specular reflections occur need to be isolated in advance; then, the specular reflections can be eliminated. Figure 3.28 shows the flowchart of proposed pupillary detection algorithm.

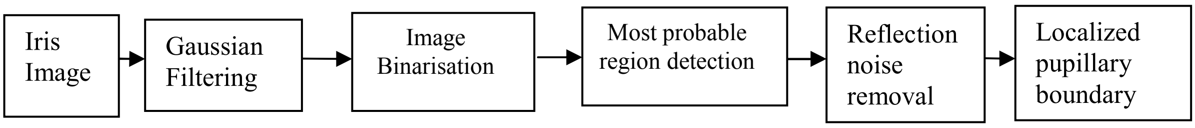


Fig. (3.28) : Flowchart of pupillary detection algorithm

Gaussian filtering :

The input eye image is initially filtered by a Gaussian filter before being submitted to intend to smooth the input image and also enhance the image contrast, mainly on the edge.

Image binarisation :

The input iris image is first binarized by a chosen threshold value. Since the intensity values of the pixels in the pupil area are small in the iris image and the area of the pupil is not large, 5 - 8% (in considering the proportion of iris region to the entire iris image for the CASIA database [9]) of the pixels with lowest intensity values are chosen and set to 1. Those pixels are assumed to include the pupil. For iris images from version 2 of the database, there is usually glare in the pupil area, which sometimes makes the detection incorrect. The inner boundary is localized by thresholding the images and freeman's chain code. Make the gray scale histogram of the image. By setting a threshold value T, change the original image into binary image B(x,y) as shown in the figure 3.29 the original image, if the gray values of pixel are bigger than T, set them as 0, on the contrary, set others to 1.

(a) (b)

Fig. (3.29) : a) Binary image b) Binary image with excluded eyelashes

Detection of the most probable region :

Binarisation process is capable of enhancing the most pupil area however; it preserves many irregular and non-connected stains having varying sizes, both inside and outside of the true pupil region. Pupil region detection is carried out relying on the analysis of the connected region. The steps involved in this process are as follows:

1. Exclude the eyelashes part of the binary image, then utilize Freeman chain code to search eight-adjacent regions, set the pixel values of these regions as According to the characteristic that the area of eyelashes is much smaller than that of the pupil, apply threshold value to binary image.
2. If , in region R, the number of pixels is smaller than M; value of which need to be decided, set them to 0. The result of the binary image excluded eyelashes (B1(x,y)) is shown in figure 3.29(b).
3. Analyse connected region: The coordinates of pupil centre and the radius of pupil of the largest connected region C is calculated by,

$$(x_p, y_p) = \frac{1}{n} \sum_{(x_c, y_c)@C}^{N} (x_c, y_c) \tag{3.25}$$

$$r = round \ (\sqrt{\frac{N}{\pi}})$$

Where, N is the number of pixel in connected region C and (X_c, Y_c) is the coordinates of connected region C is radius of circle.

3.9.2 Outer boundary detection using canny edge detector :

To complete outer boundary location, the operator of the Canny edge detector and Hough transform are used. Hough transform requires the three dimensional searching and so requires the higher computational complexity. We used Canny edge detector because it is an optimal detector in which edges are marked at maxima in gradient magnitude of Gaussian smoothened image.

The Canny edge detector :

The canny edge detector detects true edges from noisy images and suppresses the false edges due to noise in the image. Thus, Canny edge detector is suitable for outer boundary detection in Iris segmentation. Steps involved in the Canny edge detector:

1. Utilization of the Gaussian filters of standard deviation 1.5 to smooth image by minimizing the high frequency noise occurring due to eyelids and eyelashes in iris images.
2. Calculation of the gradient value and the direction of the each pixel using Sobel operator to mark edges with large gradient magnitudes.
3. Restrain the gradient values with non-maximum suppression to convert blurred edges in the image of the gradient magnitude to sharp edges so that all local maxima in the gradient images are preserved.
4. *Threshold value processing:* The edge pixels remaining after the non-maximum suppression step are marked with their strength pixel-by-pixel. Some of these are true edges in the image, but some are false edges as they are caused by the noise.to discriminate among them two thresholds are used. Edge pixels stronger than the high threshold are marked as **strong** and edge pixels weaker than the low threshold are removed and edge pixels between the two thresholds are marked as **weak.** Thus, double thresholding removes the weak edges (false edges) which are not connected strong edges and all other edges are preserved.

3.9.3 Outer boundary detection algorithm :

Based on the above discussion the steps involved in the outer boundary detection are as follows:

1. Read the Iris image from the UBIRIS/CASIA databases and convert to gray scale image, if required to restrict the computational requirement.
2. Resize the image I(x, y) to 256 X 256 size for further reduction in computational overhead and to reduce processing time.
3. Calculate the threshold from the histogram of an image. Obtain the binary edge map of image I(x, y) using canny edge detector using the threshold obtained to get the image $I_{Ref}(x, y)$.
4. Obtain another binary edge map of image, $I_{canny}(x, y)$ with using the preset threshold. However, overall time required to obtain the binary edge map $I_{canny}(x, y)$ is less than $I_{ref}(x, y)$ and that to with better edge map with minimal noise edges.

Step 4 generates the binary image of same size of input image I(x, y) using canny edge detector with preset threshold value. Figure 3.30 shows the sample grayscale images and their binary edge map with 1's where function finds edge in I(x, y) and 0's elsewhere.

las filas y 2 columnas

5. Obtain the rows and two columns in the matrix of binary edge map image, $I_{Canny\ (x,\ y)}$, containing single '1' to draw the four tangents through these four boundary points. Various steps involved in this process are:

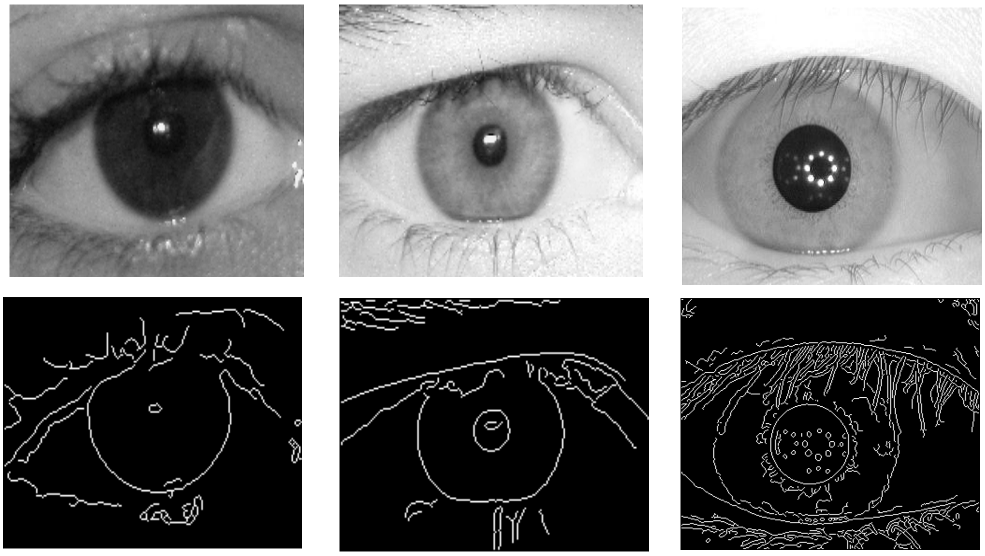


Fig. (3.30) : Edge map of an eye image using Canny edge detector.

1) The edge map image section is as shown in figure 3.31. For detecting the outer iris boundary, this matrix is read row-wise and column-wise within the range 65 and 195 to find a row and a column having single '1' with rest of the pixels '0', within the above specified range. Four such pixels (points) , two each on two rows and two each on two columns are determined.

   a) By joining the points of contacts of the two opposite tangents two diameters are obtained, D_H and D_V. The diameter of iris is computed by taking the average of these two diameters.

$$D = \frac{(D_H + D_V)}{2}$$ Thus, radius of outer boundary is R= D/2.

0	1	0	1	1	1	0
0	0	0	1	0	0	1
0	0	1	0	0	0	0
1	1	0	0	0	0	1
1	1	0	1	0	1	1

b) The point of intersection of these diameters is taken as the centre of the iris as shown in figure 3.32b.

c) The iris centre and radius thus obtained are rough estimates of the outer circle of iris. Figure 3.33 shows the accurately detected inner and outer boundary of iris.

0	0	0	0	0	1	0	0	0
0	0	0	0	1	0	0	1	0
0	0	0	0	0	0	0	0	1
0	0	1	1	0	0	0	0	1
0	0	0	1	0	0	0	0	0
0	0	0	0	1	1	0	0	0
0	0	0	0	0	0	1	0	0

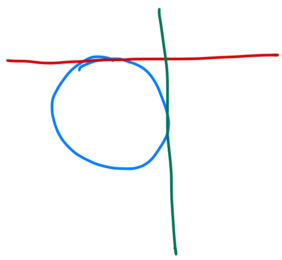
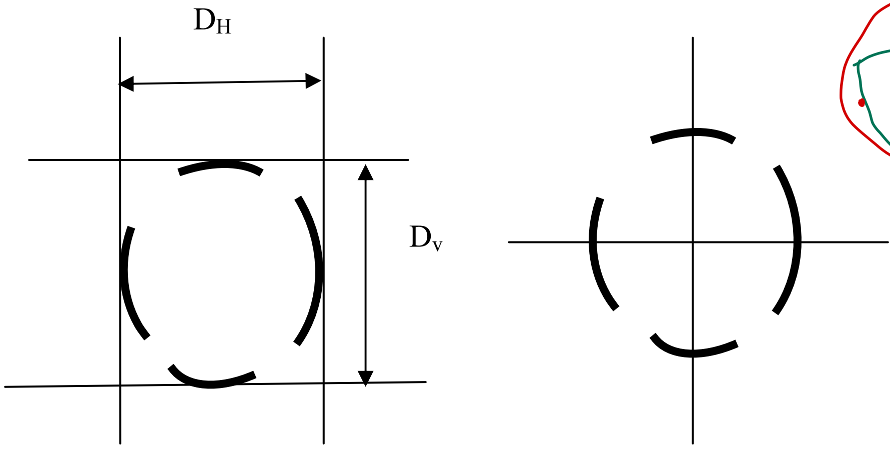
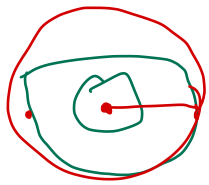


Fig. (3.31) : The part of matrix of edge map image

2) Then, four tangents are drawn through these points as shown in figure 3.32.





a) Four tangents b) Iris centre and outer radius detection

Fig. (3.32) : Estimation of center and radius of outer boundary of the iris.

3.9.4 Experimental results of proposed method 2 :

Two experiments are conducted to evaluate the performance of the proposed iris segmentation algorithm using Canny edge detector. Parameters chosen for the performance evaluation are segmentation accuracy, processing time required for segmentation and iris recognition performance when normalized iris image is used as input for feature extraction and matching. The experimental results are evaluated using MATLAB 7.10 on Intel(R) core(TM) i4 CPU at 3GHz with 4GB RAM. For each of segmentation methods, normalization, feature encoding and matching method is kept same.

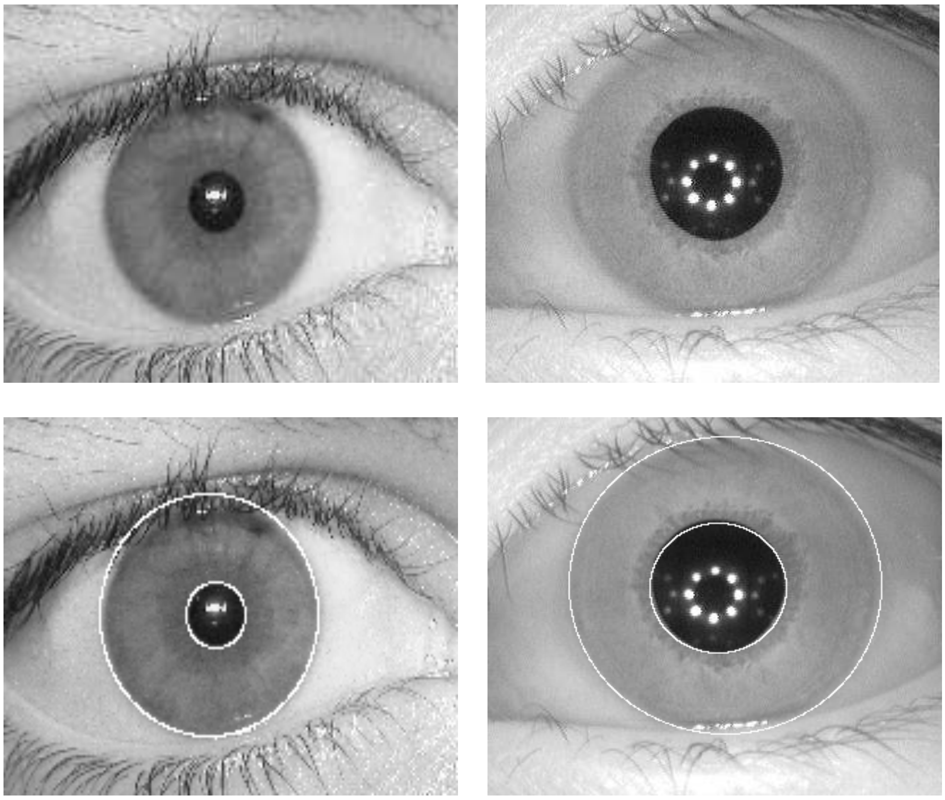


Fig. (3.33) : Inner and outer boundary detection of iris

Experiments on evaluation of segmentation performance :

Implementation of two prominent and widely used segmentation methods viz. Integro-differential operator (Daugman's Model) and Hough transform (Wilde's Model) is carried out by using freely available MATLAB Code with suitable modifications. Performance evaluation of iris segmentation algorithms is being carried out using the UBIRIS database to evaluate segmentation accuracy and processing time required by proposed method. We have used all the 1877 images of the UBIRIS database and the results of iris segmentation are tabulated in Table 3.7.

Table 3.7 Results of Iris Segmentation on UBIRIS Database

Segmentation Methods	Segmentation Accuracy(%)	Processing time of Iris segmentation		
		Minimum Time (Sec.)	Maximum Time (Sec.)	Average Time (Sec.)
Daugman's Integro Differential operator	76.06	1.26	2.09	1.67
Hough Transform (Masek Method)	90.32	1.62	2.51	2.06
Canny edge detector	89.76	0.44	0.68	0.56

Our tests on more challenging iris image database set, UBIRIS, confirmed that our proposed segmentation method using canny edge detector robust in dealing with low quality images. More importantly, the proposed method offers comparable performance with 89.76% segmentation accuracy. This performance measure is indeed encouraging due to the low quality of the images. Table 3.7 shows average processing time needed for iris segmentation is about 0.56 seconds, which is considerably smaller than other approaches.

Experiments on effect of segmentation on Iris recognition performance :

We have also implemented the feature extraction and matching stages of Daugman's system by using freely available open MATLAB codes to evaluate the effect of partial loss of iris data in segmented iris of our method on recognition rate. With the help of this implementation, iris codes of gallery set images are generated and compared with iris codes of images of probe set to obtain recognition errors, using segmented and normalised irises obtained from our segmentation results and two most referred methods as inputs to feature extraction and pattern matching module.

Table 3.8 shows the details of the gallery set and probe set used for experiments from the UBIRIS database. Table 3.9 gives the ERR and accuracy of the implemented iris recognition system at different thresholds respectively.

Table 3.8 Details of the gallery set and probe set used for experiments UBIRIS

Total classes and images in the database	**Number of images-**1877 **Number of classes-**241 **Number of images in each class-**1-9
Gallery Size (100 classes)	600
Probe set Size (Genuine Class)	450
Probe set Size (Imposter Class)	750

The EER and recognition accuracy for the UBIRIS database using different segmentation methods is given in Table 3.11.

Table 3.9: Accuracy of recognition using each segmentation method for UBIRIS database.

Segmentation method	EER	Accuracy (%)
Integrodifferential Operator	31.54	68.46
Hough transform (Masek method)	10.77	89.23
Geodesic active contours	7.43	92.57
Canny edge detector	11.21	88.79

FAR is plotted versus different threshold values as shown in figure 3.34 and figure 3.35 for CASIA and UBIRIS databases respectively.

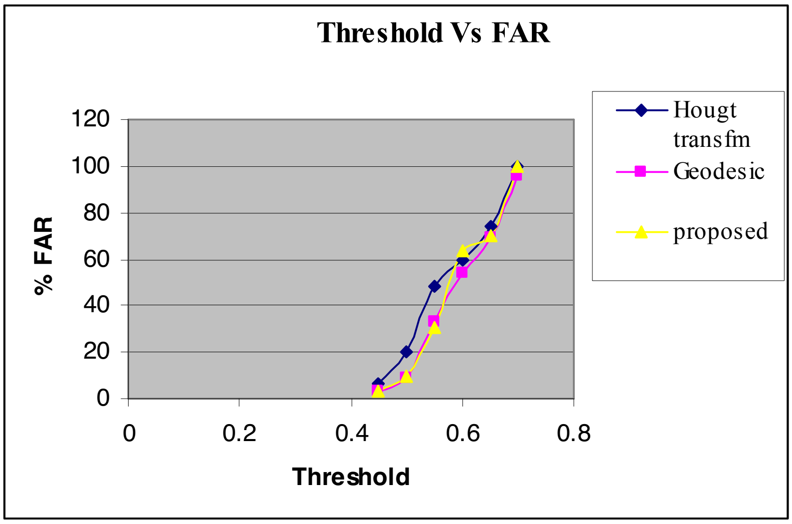


Fig.(3.34) : Threshold Vs FAR (CASIA)

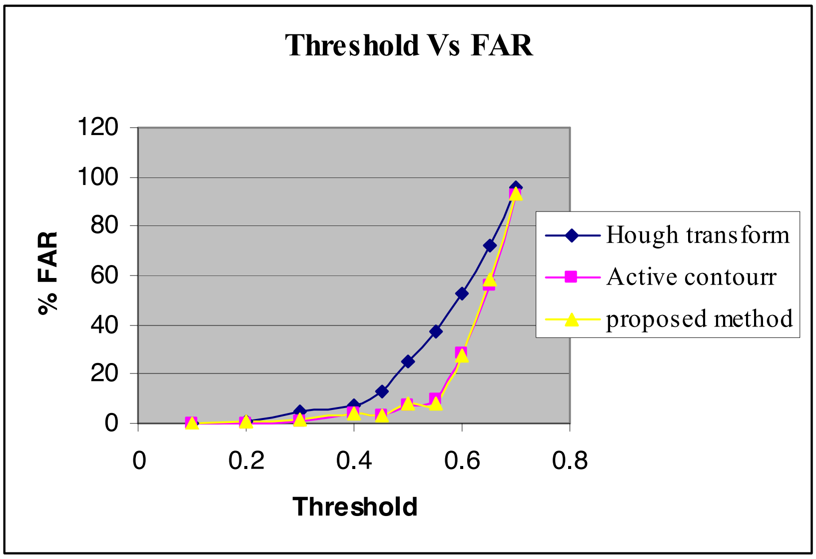


Fig. (3.35) : Plot of FAR vs. Thresholds for the UBIRIS database

3.9.5 Discussions on results :

From the results of the above stated experiments, following inferences are drawn. Time required for iris segmentation and normalization for the proposed method (0.56 seconds). As compared to Daugman's method (1.67 second) and Hough transform method (2.06 second). Improvement in the processing time as compared with the other two methods is due to following reasons:

- In the Hough transform method, two steps are involved in outer boundary detection. The first step is to convert the gray scaled eye image into a binary edge map using suitable (Canny) edge detector method and then circular Hough transform is used. In circular Hough transform, each edge pixel with coordinates (x, y) in the image space is mapped for the parameters space determining the circle parameters i.e. center and radius which resolves the circle equation. As a result the point (x, y, r) is obtained in the parameters space which represents a possible iris circle in the image, all such possible circles are obtained and then correct iris circle is drawn.
- As center and radius are different for the pupil the so, these two steps are repeated. This makes the Hough transform method computationally highest among three

methods. However, the accuracy of the segmentation is best among the three methods.

- Integro differential operator is used in the Daugman's method for detection of the both the boundaries. This operator searches for the circular path where there is greatest change in the pixel values when there is change in radius and pixel coordinates from the center of iris circle in iterative operations. The same process need to be replaced for the pupil detection. Due to repeat set of calculations for pupil and iris the method becomes computationally heavy.
- In the proposed method the outer boundary is detected using Canny edge detector and then by obtaining the four tangent points, using very fast search of edge map matrix, to find the center and radius of iris circle. This method is neither on the computationally Hough transform method nor it is iterative in nature. Pupil is detected separately by using the gradient vector approach. Moreover the centre of the iris is mapped to centre of the pupil. This further reduces the normalization time required. As processing time is saved in all the steps pupil detection, outer boundary detection and the normalization, this method is computationally very efficient as compared to other two methods.
- The iris segmentation accuracy achieved by the proposed method for UBIRIS database is slightly less (89.76%) as compared to Hough transform method (90.32%) but It is better than comparable to Daugman's method (76.06%). Hough transform method uses the pupil circle and iris circle mapping separately. However, in the proposed method little useful part of the iris is lost due to assumption of the same center for pupil and iris. This is also a reason for the slightly less segmentation accuracy.
- Recognition accuracy using the Wildes method is slightly better than that of proposed method. The conclusions drawn from this are as follows.
- The improvement in the recognition performance improvement is due to best segmentation accuracy achieved at the segmentation stage.
- Recognition performance of the proposed method is slightly lower than Hough transform method because of the loss of information in the pupil and iris

segmentation process. The recognition accuracy could be further improved by selection of better feature extraction method. Chapter 6 discusses on the quality measures for the selection of features used in feature extraction algorithm.

- The least recognition rate of the Daugman's method is due to the low success rate of the iris segmentation and presence of noise in the segmented iris image.

3.10 Concluding Remarks

Iris segmentation is probably one of the most crucial operations involved in iris recognition. Accurate iris segmentation is fundamental for the success and precision of the subsequent feature extraction and recognition, and consequently allowing the iris recognition system to achieve desired high performances.

Employing better image acquisition systems can significantly improve the quality of input images and, thereby, the recognition performance. However, for practical purposes, it is necessary to develop algorithms that can handle poor quality data. In this regard, the present chapter discusses the problem of iris segmentation in challenging images. A set of 4 iris segmentation techniques were evaluated on a noisy database containing various non-ideal factors such as occlusions, blur, and drastic illumination variations.

The pre-processing schemes appear to have a significant role in the segmentation performance for all the techniques. Similarly, eye centre detector helps in localizing a region for iris boundary search process.

The considered set of iris segmentation techniques ensures a balance between the classical approaches, and the relatively newer approaches to handle challenging iris images. Both the integro-differential operator and Hough transform require relatively less computations, when compared to the GAC techniques. However, their performance was observed to be low, due to the poor quality input data. On the other hand, Geodesic Active Contours, and canny edge detector method provide better performance, at the expense of higher computational complexity in case of active contour method.

Geodesic Active Contours can be effectively used to evolve a contour that can fit to a non-circular iris boundary (typically caused by eyelids or eyelash occlusions).

However, edge information is required to control the evolution and stopping of the contour. Based on the discussion of the experiments and results obtained, following conclusions are drawn.

1. Improvement in iris recognition accuracy depends on the segmentation accuracy as it considers the loss of iris data and noise in the image.
2. Segmentation using Canny edge detector contributes to best recognition rate because of accurate segmentation of lossless and noise free irises of actual shape.
3. Processing time required for the first method is more, while that of second method using Canny edge detector is small as compared with the other methods discussed. However, presented timings cannot be trusted completely because the processing time of algorithm depends not only on the power of the algorithm but also on other various factors like way of implementation, loops, optimization, overheads of other running processes on PC and so on. Strength of algorithms in terms of processing time can be very well estimated from the complexity of the mathematical equations involved and the basic logics used in the algorithms.
4. Recognition performance of the proposed method is slightly lower than Hough transform method because of the loss of information in the pupil and iris segmentation process. Extracting the features using the 1D LogGabor filter and using Hamming distance for matching has provided these results. The recognition accuracy could be further improved by selection of better feature extraction method. This has motivated us to device new techniques of feature extraction and selection of best quality features to be used in feature extraction algorithm. These issues are discussed in the further chapters in this thesis.

However, edge information is required to control the evolution and stopping of the contour. Based on the discussion of the experiments and results obtained, following conclusions are drawn.

1. Improvement in iris recognition accuracy depends on the segmentation accuracy as it considers the loss of iris data and noise in the image.
2. Segmentation using Canny edge detector contributes to best recognition rate because of accurate segmentation of lossless and noise free irises of actual shape.
3. Processing time required for the first method is more, while that of second method using Canny edge detector is small as compared with the other methods discussed. However, presented timings cannot be trusted completely because the processing time of algorithm depends not only on the power of the algorithm but also on other various factors like way of implementation, loops, optimization, overheads of other running processes on PC and so on. Strength of algorithms in terms of processing time can be very well estimated from the complexity of the mathematical equations involved and the basic logics used in the algorithms.
4. Recognition performance of the proposed method is slightly lower than Hough transform method because of the loss of information in the pupil and iris segmentation process. Extracting the features using the 1D LogGabor filter and using Hamming distance for matching has provided these results. The recognition accuracy could be further improved by selection of better feature extraction method. This has motivated us to device new techniques of feature extraction and selection of best quality features to be used in feature extraction algorithm. These issues are discussed in the further chapters in this thesis.