Chapter 2
Literature Survey

This chapter provides an essence of comprehensive literature survey on iris recognition algorithms based on different methodologies. This chapter begins with a brief introduction of biometric system and iris recognition system. The related work on different modules of iris recognition system *viz.* iris image acquisition, iris segmentation, feature extraction and iris matching has been presented in this chapter.

2.1 Introduction

To get better perspectives of different issues related to design iris recognition algorithms, it is of great importance to review the experiences of earlier research efforts. This helps in improvising the methodological and analytical tools used in the present study besides formulating appropriate concepts relevant for the study. Several studies have been carried out in the past on iris recognition systems. Designing of hybrid iris recognition algorithms is now getting a new impetus with the soft computing techniques like ANN, QPSO, and fuzzy logics etc. in recent decades.

In the following sections, biometric system and iris recognition system along with related work on different modules of iris recognition system have been reviewed and summarized.

2.2 Biometric System

The term biometrics is derived from two Greek words bio means *"life"* and metric means *"to measure*". It refers to the automatic individual's identification based on their physical or behavioral characteristics (Nabti *et al.*, 2007). The physiological characteristics of a person such as face pattern, iris pattern, fingerprint, palm print, hand geometry present unique information to distinguish among them and can be used in authentication applications (Alice, 2003). The biometric recognition system involves two phase *viz.* Enrollment phase and Identification or Verification phase as shown in Figure 2.1. During enrollment phase feature vector is stored in a database after being extracted from individual object. In identification or verification phase, user provides a sample vector to the system where it is compared to store vector and depending on pre-determined threshold value a decision is made (Ramkumar *et al.*, 2012). To serve any human physiological or behavioral traits as a biometric characteristic it should satisfy the following requirements (Jain *et al.*, 2004; Huang *et al.*, 2004):

- Universality : Every individual should have it.
- Distinctiveness : No two individuals should be the same.
- Permanence : It should be invariable over a given era of time.
- Collectability : The feature must be easy to collect.

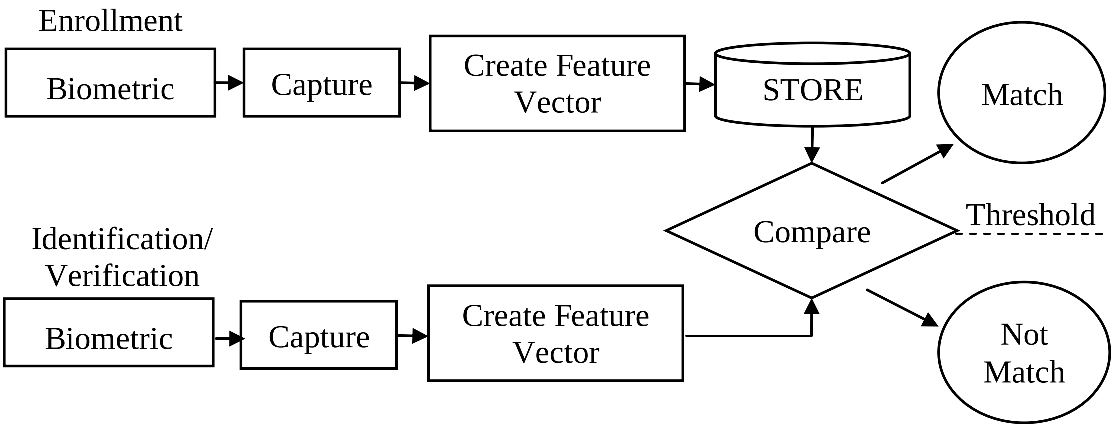

Figure 2.1 Stages of biometric system

The different biometric technologies (shown in Figure 2.2) such as fingerprint, face recognition, hand geometry, voice recognition, iris recognition, gait, palm print, facial thermogram, ear and signature recognition are used in various applications. Each biometric has its own advantages and disadvantages and no single biometric system can be considered as an optimal system (Jain *et al.*, 2004).

Due to the advancement of science and technology, application areas of biometrics are increasing day by day where identification or verification is required for individuals. The applications of biometrics can be divided into the mainly three categories *viz.*

Commercial, Government and forensic. Commercial applications include computer network login, data security, ATM, credit card, distance learning and many more. Government applications include passport control, national ID and driver's license. Criminal investigation, parenthood determination, corpse identification belongs to forensic applications of biometric systems. Unlike traditional methods based on password and PIN number, the use of biometrics provides more comfort to the user while increasing their security. For example, uses of biometrics on banking services are much safer and faster compared with the methods based on credit and debit cards (Abiyeb *et al.*, 2008).

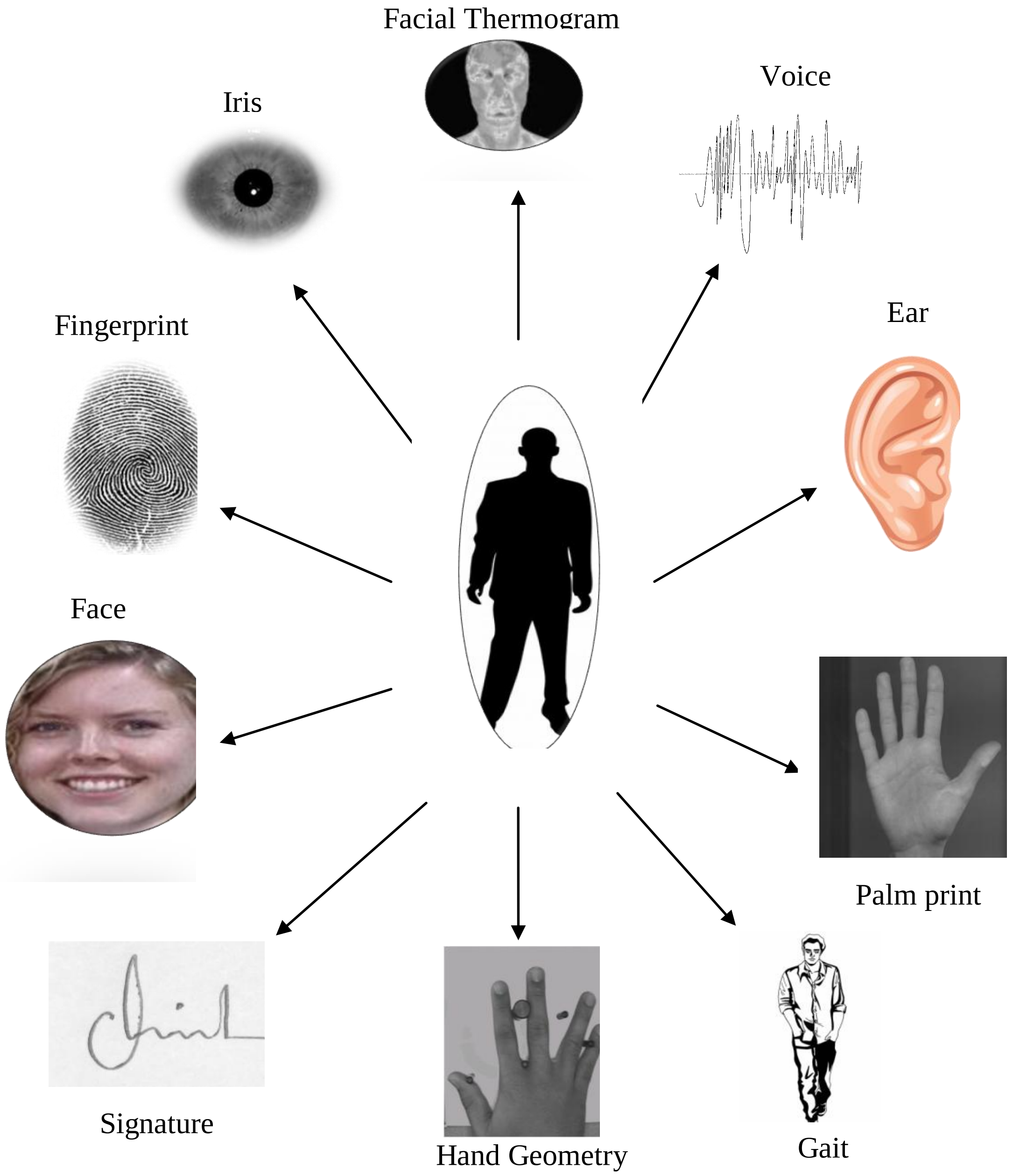

Figure 2.2 Different biometric recognition systems

Generally, the performances of biometric system is measured by using False Acceptance Rate (FAR), False Rejection Rate (FRR), Recognition Accuracy, Receiver Operating Characteristic (ROC) curve and Cumulative Match Characteristics (CMC) curve (Bodade *et al.*, 2014).

- FAR is the rate of accepting false user and is defined as:

$$FAR = \frac{No.of\ times\ unauthorize\ person\ accepted}{Total\ number\ of\ comparison} \times 100$$

- FRR is the rate of rejecting the genuine person and is defined as:

$$FRR = \frac{No.of\ times\ authorize\ person\ rejected}{Total\ number\ of\ comparison} \times 100$$

- The overall recognition accuracy of the system is defined as:

$$Accuracy = 100 - \frac{FAR + FRR}{2}$$

- The ROC curve is a plot of FAR vs TAR (TAR=100-FRR) where TAR stands for True Acceptance Rate. This curve is threshold independent, allowing comparison of different system performances under same condition or single system under different condition (Bodade *et al.*, 2014).
- The CMC curve is a plot of Recognition Accuracy vs Rank which is used to represent the identification (one-to-many comparison) performances of the system. The CMC is estimated by sorting matching score between query vector and reference vectors. The genuine matching at lower the rank represents the better one-to-many identification system (Raffei *et al.*, 2013).

2.3 Iris Recognition System

The recognition system based on iris as a biometric trait is called as iris recognition system (Daugman, 1993). An eye image (S1213L01.jpg) from CASIA Iris V3 Interval database is shown in Figure 2.3. The iris region, the part between the pupil and the white sclera, contains many minute visible characteristics such as freckles, coronas, stripes, furrows and crypts representing complex texture pattern which are unique for each individual. Furthermore, the chance of obtaining two people with same texture pattern is almost zero that makes the system efficient and reliable when high security is concerned (Jhamb *et al.*, 2011).

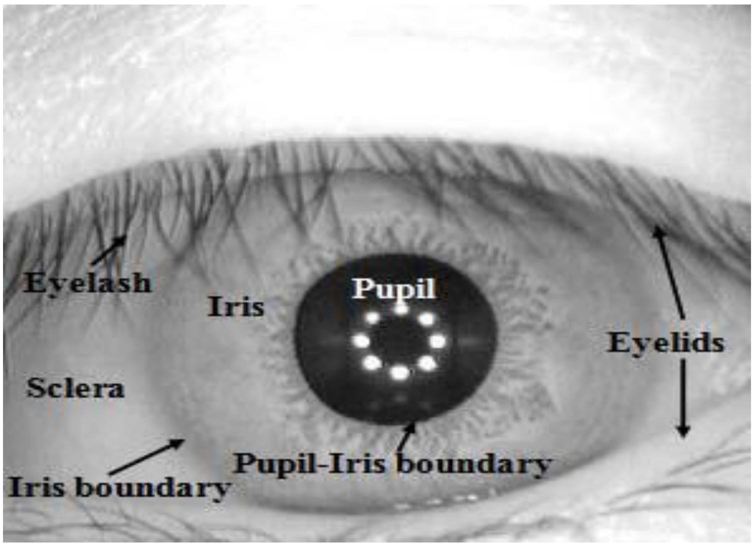

Figure 2.3 An Eye Image from CASIA Iris V3 Interval database

Typically, the iris recognition system consists of five modules *viz.* Image acquisition, segmentation, normalization, feature extraction and matching as shown in Figure 2.4. Image acquisition deals with acquiring of eye images. After acquiring the eye image, iris part is localized by demarcating its inner and outer boundaries during segmentation process. The artifacts such as eyelids, eyelashes and reflections are removed from the iris image during segmentation. As iris, made up of fibrous tissue, controls the amount of lights entering through the pupil by expanding and shrinking its tissue, its size is not consistent. Also, the centre of outer boundary (iris centre) and inner boundary (pupil centre) are not concentric. Therefore, the task of normalization process is to make the iris image size uniform. In general, Daugman's Rubber sheet Model is used for normalization which transforms Cartesian coordinates of detected iris into polar coordinates. During feature extraction process, the unique iris feature is extracted using appropriate technique from the segmented iris. Finally, the extracted features are matched with the stored pattern to validate the identification/ verification process (Daugman, 1993; Daugman, 1994; Boles *et al.*, 1998; Daugman, 2004).

Due to stability, non-invasiveness, uniqueness and epigenetic nature of an iris, iris recognition system is considered as more appropriate and suitable system to replace traditional person identification and verification system compared to other biometric systems (Bodade *et al.*, 2014). However, iris recognition system has many challenges regarding accurate iris segmentation, appropriate feature extraction and classification to achieve high accuracy recognition system. Besides these, the noises such as eyelids, eyelashes, specular reflections, lighting reflections etc. present over the iris image introduce a great challenge for segmentation process. The task of iris recognition system is to recognize an iris with less FAR and FRR. The most of the existing recognition algorithms performed well for verification of an iris image with almost zero FAR and FRR. But it is a challenge to achieve the high performance recognition system during identification of an iris image.

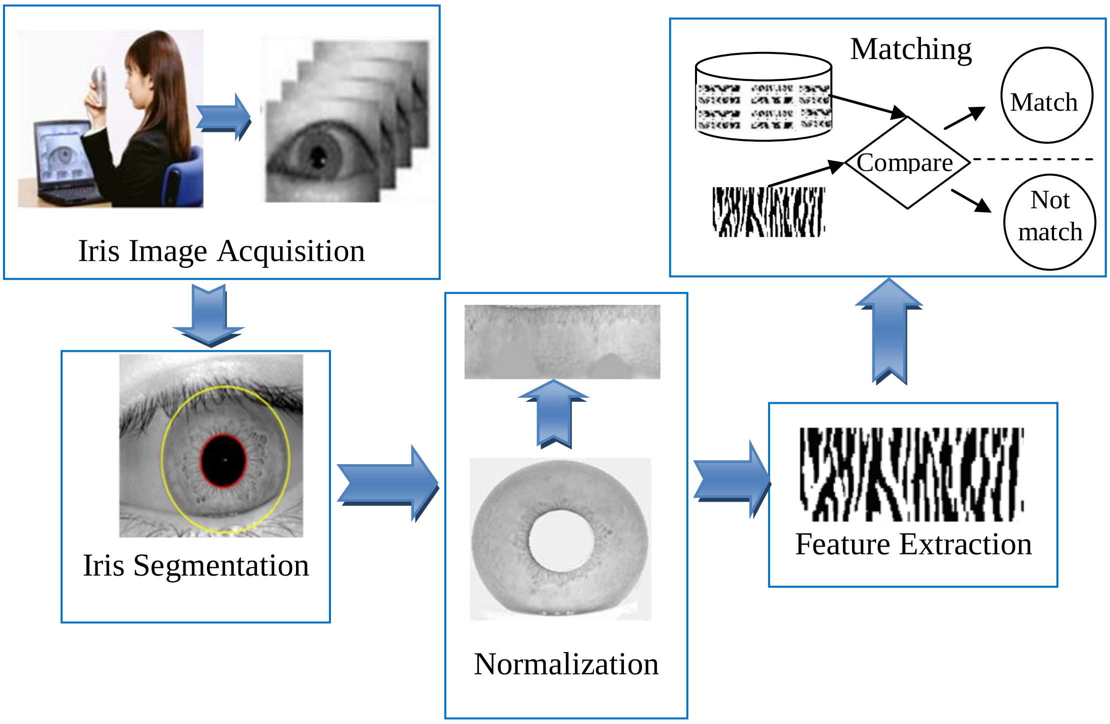

Figure 2.4 Stages of Iris Recognition System

The history of iris recognition can be traced back in the eighteenth century where police in the Paris prison distinguished criminal by inspecting the color of the irises (Huang *et al.*, 2002). Followed by Daugman's first commercial iris recognition system (Daugman, 1993), various authors proposed numerous iris recognition algorithms for real life applications. Daugman, 1993; Boles *et al.*, 1998 and Wildes *et al.*, 1997 are the pioneers in this field. These methods are based on statistical methodologies. On the other hand, iris recognition algorithms based on Soft-Computing methodologies also have been developed to take the advantage of it which have an ability to mimic behavior of the human mind in reasoning and are considered as an emerging approach to computing. Artificial Neural Network (ANN), Fuzzy Logic (FL), Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Quantum-behaved Particle Swarm

Optimization (QPSO), Support Vector Machine (SVM) etc. are the constituents of Soft-Computing methodologies. These constituents can be used independently or in combination to solve the real-life problems.

In the following sections, related work on iris image acquisition system, iris segmentation, feature extraction and iris matching have been summarized.

2.3.1 Image Acquisition System

Image acquisition deals with capturing sequence of iris images from the subject using cameras and sensors. Small size of an iris, approximately 11 mm in diameter, occluded by the eyelid, eyelashes and reflections makes the acquisition difficult. An acquisition of an iris image is the first step for any iris recognition system. Various imaging system has been developed to capture high resolution iris image as these images affect the performance of the recognition system. List of commercial iris acquisition devices are tabulated in Table 2.1.

Table 2.1 List of commercial iris acquisition devices

Product	**Operating Range (m)**	**Illumination**	**System**
Iris Access 3000	0.08-0.25	NIR	PC
Iris Access 4000	0.26-0.36	NIR	Embedded system
Iris Access 7000	0.31-0.35	NIR	Embedded system
BM-ET300	0.30-0.40	NIR	Embedded system
BM-ET200	0.30-0.40	NIR	Embedded system
IOM PassPort™	3	NIR	PC
IOM RapID-Cam™ II	0.30-0.45	NIR	Wireless Embedded system
IOM N-Glance™	0.53-0.80	NIR	Embedded system
InSight™ SD	1.5-2.5	850nm LED	PC
Insight® Duo	1.5-2.5	850 nm LED	PC
IKEMB-100	0.22-0.4	NIR	Embedded system

2.3.2 Iris Segmentation Techniques

This section presents some of the work carried out on iris segmentation. Iris segmentation is one of the very important steps of iris recognition system. The relationship between segmentation accuracy and recognition rate is identified by (Proenca *et al*, 2010). Many different techniques were used in the segmentation stage of iris recognition by different authors. Pioneering work on iris segmentation was done by Daugman (1993) and Wildes *et al.* (1997). Daugman used Integro-differential operator (IDO) whereas Wildes *et al.* used CHT and edge detection method for iris segmentation.

Many authors adopted Daugman and Wildes *et al.* approach with or without any refinements. Schunkers *et al.* (2007) applied IDO at multiple resolutions to segment the iris region. They detect lower and upper eyelids by replacing the integral along the elliptical contour in IDO with the integral along the arc-shaped boundary. These operations are preceded by the detection and removal of reflection over the eye image. The reflections are detected by using thresholding method where, threshold value, t, is selected as

$$t = \begin{cases} 160 & \text{neigbhor pixel intensity} < 50 \\ 240 & \text{otherwise} \end{cases}$$

Linear algebra and partial differential equation based iterative image inpainting technique is applied to remove the detected reflections. Rahulkar *et al.*, (2011) use the IDO for iris segmentation purpose. The segmented iris is then normalized to the fixed size of 64×360 with the help of Daugman’s Rubber Sheet Model. Grabowski *et al.* (2011) obtained the iris inner and outer boundaries by using special IDO in their hardware system designed for iris recognition. The IDO is also applied by Barpanda *et al.* (2015) to segment the iris region in order to investigate their iris feature extraction technique based on Cohen-Daubechies-Feauveau 9/7 (CDF 9/7) filter bank. Labati *et al.* (2010) performed extraction and linearization of the inner and outer edge of the iris with the help of IDO. Li *et al.* (2010) applied IDO with RANSAC algorithm for detection of upper eyelid during iris segmentation process.

Sankowski *et al.* (2010) presents iris segmentation algorithm for images acquired under visible as well as near-infrared light. This algorithm achieved rank II in NICE I contest. The complete iris segmentation is performed in series of steps. First, reflections over eye image are detected with the help of thresholding and morphological operator followed by removal of these detected reflections through inpainting. Next, iris outer and inner boundary is localized with IDO by restricting the search space to 105 degrees left and right sector of an eye image to avoid the segmentation error due to eyelids. Finally, lower and upper eyelids are detected using circular arc and line model respectively. NICE-I iris recognition contest winning algorithm proposed by Tan *et al.*

(2010) is based on new version of IDO defined by Integro-Differential ring inspired by gradient decent which accelerates the convergence of original IDO.

Ziauddin *et al.* (2009) proposed iris segmentation approach based on the concept of CHT. First, pupil region is isolated from the rest of the image by thresholding with the threshold value, t, followed by morphological operations. The value t is selected as:

$$t = i + \max(20, 0.4 \times i)$$

where, i represents pixel intensity. From the resultant binary image, pupil centre coordinates and radius is determined by morphological operations and iterative process. For iris detection, CHT is applied on edge image obtained by using (Canny, 1986) and (Wildes, 1997). A mask template is defined based on the detected centre coordinates and radius of pupil to remove the undesirable point from the edge image to speed up the process of CHT. Also, the parameter estimation for CHT is restricted based on pupil boundary to accelerate its convergence. Farouk *et al.* (2011) performed iris segmentation in 3 steps. First, iris outer boundary is located using CHT. Next, iris inner boundary is located using Discrete Circular Active Contour (DCAC). In the last step, noise regions present over the iris part is located by using Linear Hough Transform (LHT) and 1D Gabor filter. Ngo *et al.* (2014) proposed architecture design for CHT based on Field Programmable Gate Array (FPGA) technology for efficiently detection of iris boundaries. To address the memory requirement problem of CHT, modular design of CHT is adopted which would reduce the memory requirement without degrades the segmentation accuracy. Their approach consists of circle point generator which supports the 16 parallel CHT modules and best circle selector module to determine best-fit circle parameter.

Hasan *et al.* (2012) performed CHT and LHT for detection of iris boundaries. Iris outer boundary is detected first in order to reduce the search space of CHT for detection of inner pupil boundary. Marciniak *et al.* (2012) adopted HT for detection of iris boundaries from the edge-map of the eye images. The edge-maps are obtained by using canny edge detector. Umer *et al.* (2015) tries to accelerate the CHT by restricting the search in 2-D instead of 3-D search region. He *et al.* (2007) used shrunk image together with modified canny edge detector to create edge-map. The centre coordinates and radius of iris outer boundary are determined on edge-map by using HT. The pupil radius and centre coordinates are obtained by using geometrical method with the help of linear thresholding and Sobel operator. The noises such as eyelashes, reflections over segmented iris are detected with the help of linear thresholding. Rafffei *et al.* (2013) adopted Line Intensity Profile Support Vector Machine and Neighboring Intensity Interpolation method for removal of reflections present over eye image. Segmentation of iris is performed on this pre-processed image using CHT. Eyelids and eyelashes are detected by using linear HT and thresholding respectively.

Due to anatomy of an eye, the concept of Active Contour (AC) model is found to be appropriate for iris segmentation. Active Contour, also called snakes, was first proposed in 1987 by Kass *et al.* (1988). It is a method for delineating object outlines in an image. Through the interactive process, the Active Contour model fit initial set of control points to the objects in an image. The Daugman (2007) used discrete Fourier series based AC model for detection of iris inner and outer boundary. The set of N discrete Fourier coefficients, $(F_k)_{k=0}^{N-1}$, is computed from the series of L regularly spaced polar gradient data, $(r_\theta)_{\theta=0}^{L-1}$, as:

$$F_k = \sum_{\theta=0}^{L-1} r_\theta \, \mathrm{e}^{-2\pi i k\theta/L}$$

From these L discrete Fourier coefficients, new boundary is formed as $({r^*}_\theta)_{\theta=0}^{L-1}$

$$r^*{}_\theta = \frac{1}{L}\sum_{k=0}^{N-1} F_k \mathrm{e}^{2\pi i k\theta/L}$$

Farouk *et al.* (2010) employed DCAC to localize the iris inner boundary. Sometimes blurring caused by conventional misfocus or by wavefront coding degrades the image quality, thus making iris segmentation difficult. To alleviate this problem, region based active contour method is used by Boddeti *et al.* (2010) for iris segmentation. Active Contour method is also adopted by Roy *et al.* (2011) and Lefevre *et al.* (2013) to get precise boundaries of an iris.

Vasta *et al.* (2008) proposed two-stage iris segmentation approach based on elliptical model and Mumford-Shah Functional. Matveev *et al.* (2013) address the initial circular approximation during iris segmentation with circular shortest path algorithm. He *et al.* (2009), proposed hybrid iris segmentation approach based on Adaoost-cascade iris detector, elastic and spline based curve edge fitting model. Zubi *et al.* (2007)

presented iris segmentation approach using HT along with polynomial fitting and morphological operations. Game theoretic decision making procedure which integrates region based and gradient based segmentation method proposed by Roy *et al.* (2012) for robust iris segmentation. Table 2.2 summarizes some of the iris segmentation techniques employed by various authors in the literature.

Table 2.2 Iris segmentation techniques

Method	**Segmentation Techniques**	**Purpose**
Daugman (2007)	Active Contour	Discrete Fourier series based AC model is used for detection of iris inner and outer boundary
He *et al.* (2007)	Geometrical method, modified canny edge detector, CHT	Pupil boundary is detected using geometrical method; edge map of shrunk image created by modified canny edge detector; iris centre coordinates and radius are obtained on edge map by using CHT
Zubi *et al.* (2007)	HT with polynomial fitting and morphological operation	Iris segmentation is performed by using hybrid of HT and polynomial fitting
Vatsa *et al.* (2008)	Elliptical Model and Mumford-Shah Functional	Iris segmentation is performed in two stages: First, elliptical model is used to estimate the iris boundaries. Next, Mumford-Shah Function is used to compute exact iris boundaries
He *et al.* (2009)	Adaboost-cascade iris detector, elastic model, spline-based edge fitting	Adaboost-cascade iris detector is used to extract rough position of iris centre. Elastic model and spline-based edge fitting is used for iris segmentation
Ziauddin *et al.* (2009)	Thresholding, edge detection, CHT	Thresholding is used to isolate pupil. Edge detection and CHT is used to locate iris outer boundary
Schunkers *et al.*(2010)	Thresholding, inpainting, IDO	IDO is applied at multiple resolutions to segment iris, noises are detected and removed by thresholding and inpainting technique. IDO is used to estimate gaze direction
Labati *et al.*(2010)	IDO with linearization; Gabor filter; Thresholding	IDO is used to identify the boundaries and then iris linearization is performed for fine localization of pixels in the boundaries; Gabor filter and thresholding are used to remove the noises
Li *et al.* (2010)	IDO with RANSAC	IDO with RANSAC algorithm is used to detect upper eyelid
Farouk *et al.* (2010)	Discrete Circular Active Contour (DCAC)	Iris inner boundary is located by using DCAC
Tan *et al.* (2010)	new version of IDO defined by Integro-Differential ring	Inspired by gradient decent, new version of IDO accelerates convergence of original IDO

Table 2.2 Iris segmentation techniques (Continued…)

Method	Segmentation Techniques	Purpose
Boddeti *et al.* (2010)	Region based Active Contour	Region based active contour is used for segmentation to alleviate problems caused by blurring iris image
Rahulkar *et al.*(2011)	IDO, Rubber Sheet Model (RSM)	IDO is used to perform iris segmentation; normalization is performed using Rubber Sheet Model
Grabowski *et al.*(2011)	Refined IDO, Rubber Sheet Model	Refined IDO is used to perform iris segmentation where sudden changes in gradient in original IDO is replaced with maximum change during Gaussian filter; normalization is performed using Rubber Sheet Model
Farouk *et al.* (2011)	CHT, DCAC, 1D Gabor filter, Linear HT	CHT is used to locate iris outer boundary; DCAC is used to locate iris inner boundary; Linear HT is used to isolate upper and lower eyelids; 1D Gabor filter is used to isolate eyelashes
Roy *et al.* (2011)	Active Contour Method	Active contour method, shape guided approaches and Mumford-Shah function are used for Iris segmentation
Hasan *et al.* (2012)	Linear HT, CHT, canny	Edge-map of the eye images are obtained by canny edge detection method. CHT is performed on edge-map for demarcating iris boundaries. Linear HT is used to detect eyelid and eyelashes
Marciniak *et al.* (2012)	HT, Kovesi algorithm	Edge-map is created using modified Kovesi algorithm based on canny edge detector. Iris boundaries are detected using HT
Roy *et al.* (2012)	Game theory	Game theoretic decision making procedure is employed to segment iris
Raffei *et al.* (2013)	LIPSVM, CHT, linear HT, thresholding	Reflections are removed using LIPSVM. CHT is used to demarcate iris boundaries. Linear HT and thresholding is adopted to remove eyelids and eyelashes respectively
Lefevre *et al.* (2013)	Active Contour Method	Active Contour model is used to get precise contour of the pupil and iris
Ngo *et al.* (2014)	CHT	Modular design of CHT is adopted to reduce the memory requirement during iris segmentation
Barpanda *et al.* (2015)	IDO, RSM	IDO is used to perform iris segmentation; normalization is performed by Rubber Sheet Model

Table 2.2 Iris segmentation techniques (Continued…)

Method	Segmentation Techniques	Purpose
Umer *et al.* (2015)	Constrained CHT	Constrained CHT is used to restrict search space of in 2-D

2.3.3 Feature Extraction Techniques

This section presents some of the related work on iris features extraction. Many different feature extraction techniques such as Discrete Cosine Transform (DCT), Wavelet Transform (WT), Gabor filter, 1-D Log Gabor filter, Local Binary pattern etc. were used by different authors.

Daugman (2007) and Proenca *et al.* (2007) produce an iris code by using Gabor filter. Shamsafar *et al.* (2013) encode iris code by using 1D log-Gabor and haar wavelet transformation. 1D signal of iris is decomposed by haar wavelet and binary code is obtained according to the sign of detailed coefficients of decomposition. Monro *et al.* (2007) used differences of DCT coefficients to obtain the iris code. Laplacian of Gaussian and derivative of Gaussian are employed by Chou *et al.* (2010) in order to detect ridge and step edge of an iris. Sun *et al.* (2009) proposed Multilobe Differential Filters (MLDFs) for ordinal iris feature extraction to model the flexibility of ordinal measures. Xu *et al.* (2008) obtained iris code by utilizing Intersecting Cortical Model (ICM) network. Rahulkar *et al.* (2011) computed iris features by using 2 dimensional Fast Discrete Curvelet Transform (FDCT).

Filho *et al.* (2013) also adopted WT for extraction of iris features. Feature extraction based on Local Binary Pattern (LBP) is adopted by Li *et al.* (2014) to encode iris features. Table 2.3 summarizes some of the feature extraction techniques adopted by different authors in the literature.

Table 2.3 Feature extraction techniques

Method	Feature Extraction Techniques	Purpose
Daugman. (2007)	2D Gabor filter	Obtained binary representation of iris using Gabor filter
Proenca *et al.* (2007)	2D Gabor filter	Obtained binary representation of iris using Gabor filter
Monro *et al.* (2007)	DCT	Used differences of DCT coefficients based iris coding
Chou *et al.* (2010)	Laplician of Gaussian (LoG) and Difference of Gaussian (DoG)	Ridge edge and step edge are detected using LoG and DoG

Table 2.3 Feature extraction techniques (Continued…)		
Method	**Feature Extraction Techniques**	**Purpose**
Xu *et al.* (2008)	ICM network	Iris features are extracted using ICM network
Rahulkar *et al.* (2011)	FDCT	Iris features are extracted using 2 dimensional FDCT
Filho *et al.* (2013)	Wavelet Transform	Real valued and binary features are extracted using Wavelet Transform
Shamsafar *et al.* (2013)	1D log-Gabor, 1D haar wavelet	Detailed and coarse representation of iris is done by 1D log-Gabor and haar wavelet respectively
Li *et al.* (2014)	LBP	Local texture of iris is extracted using LBP
Umer *et al.* (2015)	Texture code matrix	Features are extracted from co-occurrence matrix obtained from texture code matrix

2.3.4 Iris Matching Techniques

This section presents the survey of iris matching techniques. Different iris matching techniques were used by various authors. Daugman (2007), Proenca (2007), Vasta *et al.*, (2008), Miyazawa *et al.*(2008), Chou *et al.* (2010), Shamsafar *et al.* (2013) and Tan *et al.*(2014) employed statistical Hamming Distance (HD) method for iris recognition. Velisa *et al.* (2009) employed weighted HD for recognition of an iris.

Chou *et al.* (2010) proposed normalized HD Distance to calculate matching score between Edge-type descriptor code (ETcode) of two iris images. Hollingsworth *et al.* (2010) proposed score fusion strategy for iris recognition with fragile bit distance and HD. Pillai *et al.* (2011) presented a framework based on sparse representation and random projections for robust iris matching and privacy enhancement. Dong *et al.* (2011) introduced class-specific weight-map (improvement of HD) for iris matching. Sudha *et al.* (2007) and Roy *et al.* (2012) used Hausdorff distance function to compute similarity between two iris codes. Rahulkar *et al.* (2012) proposed *k*-out-of-*n*, a post classifier to perform decision level fusion of curvelet coefficients. Filho *et al.* (2013) introduced novelty filter concepts to perform iris matching which can compare both binary and real valued iris features.

Designing of iris recognition algorithms is now getting a new impetus with the soft computing techniques like ANN, MNN, Learning Vector Quantization (LVQ), SVM, fuzzy logic etc. in recent decades. Farouk *et al.* (2010), Abhyankar *et al.* (2010), Rashad *et al.* (2011), Lefevre *et al.* (2013), Umer *et al.* (2015) and Mozumder *et al.* (2015; 2016) employed SC based technique for accurate iris recognition. Tallapragada *et al.* (2012) proposed hybrid model based on SVM and Hidden Markov Model for iris recognition. Rai *et al.* (2013) also adopted hybrid approach for iris recognition. SVM and HD are combined to perform the recognition of iris pattern. Table 2.4 summarizes the iris matching techniques employed by various authors in the literature.

Table 2.4 Iris matching techniques

Method	**Matching Techniques**	**Purpose**
Daugman (2007)	HD	To calculate matching score between two iris templates using HD
Proenca *et al.* (2007)	HD	To calculate matching score between two iris templates using HD
Thornton *et al.* (2007)	Probabilistic approach	Probabilistic approach is adopted for iris matching
Sudha *et al.* (2007)	Hausdorff Distance	To calculate matching score of irises using Hausdorff Distance
Vatsa *et al.* (2008)	HD	To calculate matching score between two iris templates using HD
Miyazawa *et al.* (2008)	HD	To calculate matching score between two iris templates by using HD
Velisa *et al.*(2009)	weighted HD	To calculate weighted HD score between binary iris codes generated by directionlets wavelet transform
Chou *et al.* (2010)	Normalized HD	Distance between ETcode of two iris is calculated using normalized HD
Farouk *et al.* (2010)	Multi-dimensional ANN	Iris image is recognized using multi-dimensional neural network
Rashad *et al.* (2011)	LVQ	LVQ network is employed for iris matching
Pillai *et al.* (2011)	Sparse representation and random projections	Framework based on sparse representation and random projections is proposed for robust iris matching and privacy enhancement
Dong *et al.* (2011)	Personalized weight map	Introduced class-specific weight-map (improvement of HD) for iris matching
Roy *et al.* (2012)	Hausdorff Distance	To compute dissimilarity between two iris codes by using Hausdorff distance function
Rahulkar *et al.* (2012)	*k*-out-of-*n*:A post classifier	To perform Decision level fusion of curvelet coefficients using *k*-out-of-*n*: A post classifier
Rai *et al.* (2013)	SVM and HD	Combination of SVM and Hamming distance are employed for recognition of iris pattern

Table 2.4 Iris matching techniques (Continued…)

Method	Matching Techniques	Purpose
Filho *et al.* (2013)	Novelty Filter	To perform iris matching using novelty filter concepts which can compare both binary and real valued iris features
Lefevre *et al.* (2013)	SVM	SVM is employed for iris recognition
Mozumder *et al.* (2015)	ANN	Feed-forward neural network is employed for iris classification
Umer *et al.* (2015)	SVM	Multi-class recognition system is developed using SVM
Mozumder *et al.* (2016)	MNN	Modular neural network with fusion technique is used for iris recognition

2.4 Chapter Summary

This chapter presents literature survey and the current state of research in the field of iris recognition system. The primary focus of literature survey was to identify SC methodologies to be employed for the present study besides formulating appropriate concepts relevant to the study.

Previous studies have shown that iris is one of the most acceptable biometric due its non-invasiveness and epigenetic nature. It is also observed that certain challenges of existing iris recognition algorithms can be addressed by using SC based hybrid algorithms. Iris Segmentation is one of the very important steps of iris recognition system. Many different techniques are used in the segmentation stage of iris recognition by different researchers. However, iris recognition system has many challenges regarding accurate iris segmentation. The following chapter presents the proposed iris segmentation approach along with the experimental results and analysis.