1.1 Introduction: Biometric Technology

With an increasing emphasis on security, the need for automated personal identification system based on biometrics has increased significantly over past few years. Existing methods of authentication like passwords and electronic cards have the risk of fraud and theft. Recently biometrics are gaining more attention for authentication of a person. A growing number of biometric technologies have been proposed over the past several years. A biometric system provides automatic recognition of an individual based on some sort of unique feature or characteristic possessed by the individual. Biometric systems have been developed based on fingerprints, facial features, voice, hand geometry, handwriting, the retina, and the one presented in this thesis, the iris.

Biometrics [1,2] can be divided into two main classes: physiological and behavioural. The physiological class is related to the shape of the body including fingerprint, face recognition, DNA, palm print, hand geometry and iris recognition. The behavioural class is related to the behaviour of a person and includes typing rhythm, gait and voice. Recently, iris recognition is becoming one of the most important biometrics used in recognition when imaging can be done at distances of less than two meters. This importance is due to its high reliability for personal identification [3]. Human iris has great mathematical advantage that its pattern variability among different persons is enormous because iris patterns possess a high degree of randomness. In addition, iris is very stable over time. Since the concept of automated iris recognition was proposed in 1987, many researchers worked in this and proposed many powerful algorithms. These algorithms were based on the texture variations of the iris and can be divided into many approaches [4], phase-based
methods [5], zero-crossing representation [6], texture analysis [7], and intensity variations [8]. The performance of these methods is assessed by using the various databases available in public domain [9-11]. Most relevant algorithms and widely used in current real applications are the algorithms developed by Daugman [12-18].

The first time an individual uses a biometric system is called an enrollment. In enrollment, a biometric system is trained to identify a specific person. The person first provides an identifier, such as an identity card. Depending on the application, biometric systems can be used in one of two modes:

1. **Verification**: This is also called as authentication—is used to verify a person’s identity—that is, to authenticate an individual that he is the same who he claims to be.

2. **Identification**: Identification is used to establish a person’s identity—that is, to determine who a person is.

   In **verification** mode, the system performs a one-to-one comparison of a captured biometric with a specific template stored in a biometric database in order to verify the individual as the person he claims to be. This process may use a smart card, username or ID number (PIN) to indicate which template should be used for comparison.

   In **identification** mode, the system performs a one-to-many comparison against a biometric database in attempt to establish the identity of an unknown individual. The system will succeed in identifying the individual if the comparison of the biometric sample to a template in the database falls within a previously set threshold. To find a match, instead of locating and comparing the person’s reference template against his or her presented biometric, the trial template is compared against the stored reference templates of all individuals enrolled in the system.

### 1.2 Iris Recognition Overview

Iris Recognition is the process of recognizing a person by analyzing the random patterns of the iris. It is, perhaps, the most reliable biometrics method for person authentication due to several crucial factors including rich and unique textures of the iris, non-invasiveness, stability of iris pattern throughout the person’s lifetime, public acceptance and availability of user friendly capturing devices.
1.2.1 Advantages of iris recognition:

1. It is an internal organ that is well protected against damage and wear by a highly transparent and sensitive membrane. This distinguishes it from fingerprints, which can be difficult to recognize after years of certain types of manual labour.
2. The iris is mostly flat, and its geometric configuration is only controlled by two complementary muscles that control the diameter of the pupil. This makes the iris shape far more predictable than, for instance, that of the face.
3. The iris has a fine unique texture that like fingerprints is determined randomly during embryonic gestation. Even genetically identical individuals have completely independent iris textures.
4. An iris scan is similar to taking a photograph and can be performed from about 10 cm to a few meters away. There is no need for the person being identified to touch any equipment; this eliminates an objection that has been raised in some cultures against fingerprint scanners.
5. While there are some medical and surgical procedures that can affect the colour and overall shape of the iris, the fine texture remains remarkably stable over many decades.

1.2.2 Iris anatomy:

The human iris is an annular part between the pupil (generally appearing black in an image) and the white sclera has an extraordinary structure. This provides many interlacing minute characteristics such as freckles, coronas, stripes, furrows, crypts and so on. Figure 1.1 shows the typical iris texture with visible characteristics which are unique to each subject. The uniqueness of the iris pattern is the direct result of the individual differences that exist in the development of the anatomical structures in the body. Some research work has also stated that the iris is essentially stable over a person’s life. Furthermore since the iris is an internal organ as well as externally visible, iris-based personal identification systems can be noninvasive to their users, which is of great importance for practical applications. All these desirable properties (i.e., uniqueness, stability, and noninvasiveness) make iris recognition a particularly promising solution to security.
Figure 1.2 shows a typical iris image from iris database with different parts. The iris begins to form during the third month of gestation and the structure is completed by the eight month, although pigmentation continues into the first year after birth [19]. The visible features of the iris are meshwork of connective tissues with arching ligament, crypts, contraction furrows, a corona and pupillary frill, coloration and freckles.

**Fig. (1.1) : Typical iris texture**

Since the appearance of each iris depends on the initial conditions in the embryonic mesoderm from which it develops, the phenotypic of two Irises with the same genetic genotype (e.g. identical twins or the both eyes of a subject) have distinguishable minutia. Past studies by Daugman about the iris texture concluded that the inter-subject variability of its pattern spans about 250 degrees-of-freedom and have entropy of about 3.2 bits per square-millimetre [14].

**Fig. (1.2) : Typical Iris image**
The iris is an externally visible, yet protected organ whose unique pattern remains stable throughout adult life. These characteristics make it very useful for use as a biometric for identifying individuals. Image processing techniques can be employed to extract the unique iris pattern from a digitized image of the eye, and encode it into a biometric template, which can be stored in a database. This biometric template contains an objective mathematical representation of the unique information stored in the iris, and allows comparisons to be made between templates.

1.2.3 Iris Databases:
For the performance evaluation of recognition system iris images from publicly available databases can be used. There are many databases recently available such as Multimedia University (MMU), West Virginia University (WVU), Iris Challenge Evaluation (ICE), Lions Eye Institute (LEI), Chinese Academy of Sciences' Institute of Automation (CASIA) and University of Beria Interior (UBIRIS). Figure 1.3 shows the typical iris images of various databases [9-11]. Experimentation of this research work is carried out on the CASIA (Chinese Academy of Sciences' Institute of Automation version) version 3 Iris-Interval database and UBIRIS database. Iris images of CASIA-Iris-Interval were captured with their self-developed close-up iris camera. The most compelling feature of their iris camera is that they have designed a circular NIR LED array, with suitable luminous flux for iris imaging. Because of this novel design, that iris camera can capture very clear iris images. CASIA-Iris-Interval-V3 is well-suited to study the detailed texture features of iris images. The images were captured indoor in two sessions for most iris images. There are 395 classes with total 2,639 images are available with the resolution of 320×280. In UBIRIS database, there are 241 classes with 1877 images. It incorporate images with several noise factors thus permitting development of robust iris recognition system.

1.3 The Iris Recognition System and Challenges
The system is composed of a number of sub-systems, which correspond to each stage of iris recognition. Typical iris recognition system is shown in figure 1.4. The input to the system will be an eye image, and the output will be an iris template, which will
provide a mathematical representation of the iris region. These stages are segmentation – locating the iris region in an eye image, normalization – creating a dimensionally consistent representation of the iris region, feature encoding – creating a template containing only the most discriminating features of the iris and finally matching of the features.

Fig.(1.3) : Typical iris images of various databases
Iris recognition has many challenges in terms of image acquisition of non-cooperative subjects, accurate segmentation of iris from remaining parts of eye images, iris analysis and its appropriate representation to create distinct feature vector to achieve high accuracy of recognition. Typical iris recognition process is basically divided into following stages.

**Fig.(1.4) :** Typical Iris Recognition System

### 1.3.1 Image acquisition stage:
Various iris databases available in public domain are discussed in section 1.2. Due to various capturing device characteristics and non-cooperation of the subject, iris recognition becomes challenging. Images are randomly selected from different databases. Comparison of UBIRIS, CASIA and MMU databases based on iris quality,
regarding focus, reflections and visibility of iris according to the image capturing session shows that UBIRIS database is the one that contains a relatively larger number of noisy pixels within the captured iris regions which is the main challenge.

1.3.2 Iris segmentation stage:
The major challenges in accurate iris segmentation of images with occlusion of iris by eyelids and eyelashes, off angle images, specular reflection in images, low intensity gradient at inner and outer iris boundary, poor focus and blurring of the images. This is shown in figure (1.3d). Variants of the stated approaches have since been used by a number of researchers with certain modifications in order to improve performance by overcoming one or multiple challenges stated earlier. Some of the other challenging areas are that the iris and the pupil are noncircular, and the shape varies depending on how the image is captured.

1.3.3 Iris normalisation stage:
Robust representations for iris recognition must be invariant to changes in the size, position, and orientation of the iris patterns. Segmented iris ring from an eye image has various inconsistencies including stretching of the iris caused by pupil dilation due to various levels of illumination, varying distance between subject and camera, rotation of the camera, head tilt and the rotation of the eye within the eye socket etc. In order to compensate these inconsistencies, it is transformed from Cartesian coordinate system to polar coordinate system. This is called as normalisation and accomplished through a method similar to the Daugman’s rubber sheet model [16-18].

1.3.4 Feature extraction stage:
As the resolution of the iris can be high, it is not practical in terms of efficiency, storage and accuracy to take every pixel as feature and describe them as feature vector. It is necessary to extract only subset of pixels from an image, either in original domain or transformed domain. In order to provide accurate recognition of individuals, the limited but most discriminating information present in an iris is extracted and significant features are formed. These features are either local or global features of iris extracted either in spatial domain or transformed domain or can be in statistical form. Daugman’s approach [18] and Wildes’ approach [19-21] in iris
recognition motivated researchers to investigate various methods of feature extraction which are broadly categorised in three groups: filter based methods, transform based methods and texture based statistical methods.

1.3.5 Feature comparison:
The extracted features are stored in database. The iris image to be tested is converted into feature vector and then it is compared with database vector for recognition purpose. The simple approach is template matching, where all iris images are stored in database and input image will be compared one by one for matching or recognition. Feature vectors are compared through different thresholding techniques like Hamming Distance, weight vector and winner selection, dissimilarity function, neural network based classification etc. The main challenge in feature extraction is to represent randomly oriented texture of iris which is available in various directions and orientations in compact feature vector so that improved recognition rate with reduced processing time and reduced computational cost is achieved.

1.4 Motivation and Problem Definition

Literature survey on the iris recognition methods reveals the following points related to iris segmentation, feature extraction, and quality assessment.

- Iris is a rich texture image containing information in multiple directions.
- Iris segmentation has been carried out mostly assuming circular pupillary and limbic boundaries which is seldom true. Although, few researchers assumed elliptical shape for iris segmentation to achieve better results, accurate iris segmentation without assumption of any fixed shape has not been addressed.
- Iris recognition is presently used for several purposes with very satisfactory results. Under rigid image capture conditions it is possible to obtain good quality images and achieve impressive accuracy with very low error rates. However, these low error rates substantially increase, specially the false rejections, when the images do not have enough quality and the captured irises contain several other types of information.
• The iris segmentation challenges, which are highlighted by the non-cooperative image setting, motivated the segmentation proposal. It is based on the creation of an intermediate image, used in the construction of the edge-map.

• Majority of the methods stated, use either one or the other kind of wavelet transform for computational efficiency or Gabor filter for appropriate iris representation to extract the iris features.

• Feature recognition using wavelet packet neural network has been found to be very useful for texture recognition and it has not been researched substantially for iris recognition.

• Quality assessment of the iris images plays a crucial role in improving the iris recognition accuracy further. This information is useful for feature quality and selection proposals to perform the biometric recognition on noisy iris images, in order to increase their robustness to noise and image heterogeneity.

• It has been observed from the literature survey that commonly the noise regions of the captured irises are localized in some subpart of the iris. Thus, the proposal for the division of the segmented and normalized iris image into different sub-regions and to perform independent feature extraction and comparison on each sub-region to enhance the iris recognition performance.

1.5 Objectives of the Proposed Work

• To review and study the different iris recognition systems.

• To develop a fast and accurate iris segmentation method especially for the images of realistic UBIRIS and CASIA V3 databases.

• To analyze the performance of recognition system using different segmentation algorithms for improved iris texture extraction.

• To investigate methods of feature extraction from iris images using Principal component analysis (PCA), 2D Gabor and Wavelet packet neural networks using different distance metrics for global and local approach and evaluate the suitability of Wavelet packet for iris recognition.

• It has been observed that, the present iris recognition methods suffer from less robustness to influence of noise. So, more robust iris recognition method is
proposed to deal with noise and achieve accurate recognition for images captured within non-cooperative environments. This will help obtaining the minimal recognition error rates.

- To devise a technique to minimise the adverse effects of noise present in the input images such as occlusion due to eyelids and eyelashes, blur and defocusing. This is accomplished by developing an effective masking technique for noisy region of the images.

1.6 Salient Contributions of the Work

This research achieves improvements in performance of iris recognition system by resolving some problems that cause errors in iris recognition system. The main contributions of this thesis include:

- The proposal of a more robust iris segmentation method able to deal with highly noisy iris images captured in less constrained conditions and non-ideal environments. This segmentation algorithm reduces error percentage when there are types of noise such as iris obstructions and specular reflection.
- Out of available series of iris images, one needs to segregate images based on their quality. A new method is proposed to evaluate quality of the iris image and separate out images useful for further processing.
- A method based on energy content is proposed to further compact the features which are already compacted, yielded by Wavelet packet encoding technique.
- A two stage de-noising is proposed to significantly eliminate effect of noise on final result.

1.7 Thesis Organization

The thesis of this research work consists of seven chapters. The brief contents of these chapters are as follows.

**Chapter-1** introduces fundamentals of biometrics with special focus on iris recognition. The challenges involved at various stages of iris recognition are discussed in detail. The motivation and objective of this research work is also detailed in this chapter.
Chapter-2 introduces the comprehensive literature review of existing iris recognition techniques. The literature survey is divided mainly into the four sections. Detailed review of the existing methods for iris localization/segmentation stage is given in section one. Literature survey on iris analysis along with existing methods for iris feature extraction and encoding stage is detailed in section two. Section three describes the existing methods for iris template matching. Review of quality performance measures in iris recognition methods is discussed in section four. Finally, the inferences are drawn from this literature survey and relevance of the proposed work has been defined.

Chapter-3 summarizes the most common iris segmentation methods and reports their robustness when dealing with noisy images. Based on this, more robust iris segmentation method for noisy images is proposed. It also discusses various steps as pre-processing 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.

Chapter-4 describes feature extraction from normalized iris using PCA and Gabor filter. In PCA analysis, effect of feature dimension on recognition accuracy is discussed. From Gabor filtered images statistical features such as mean, standard deviation are computed. In addition, the analysis of result obtained is carried out and suitability condition of applicability of 2D-Gabor wavelet is also stated.

Chapter-5 discusses about the noisy biometric recognition with particular emphasis on the UBIRIS database. The discrete wavelet transform (DWT) is applied on a set of iris images and features such as energy, standard deviation are extracted from the detail coefficients of the DWT decomposed images at variety scales. These are called as wavelet feature. This chapter also contains the feature extraction method using wavelet packet neural network (WPNN). The implemented techniques are tested on UBIRIS and CASIA V3 database and their results are discussed.

Chapter-6 aims to present, firstly a novel iris recognition method based on Wavelet transform representing local texture information and encoding local variation across
different wavelet coefficients. Our experiments illustrate the effectiveness in extracting rich local and global information of iris texture when combined with simultaneously multi-blocks and multi-channel method. From the input sequence of iris images, high quality images need to be identified. The performance of quality assessment algorithm and feature selection schemes is evaluated on the selected set of iris images possessing typical characteristics. Further, the method is proposed to assign different weights to different iris region to compare two iris features which significantly increases the accuracy. Obtained results show a performance improvement of iris recognition system by incorporating proposed quality measures in the typical system.

Chapter-7 gives the conclusion, summarizes our achievements and recommendations for future researches.