Chapter – 2

Review of Literature

A handful researches have been done in the field of biometric recognition system. Iris biometric research is an exciting, broad and rapidly expanding field. Several eminent researchers have proposed various techniques for the acquisition of iris images, segment the iris with inner and outer boundaries i.e. find the papillary and limbic boundaries, extraction of iris features for personal authentication. An extensive study starting from the view point to improve the performance of personal authentication with the concern of noisy irises, more focusing on iris template protection have been thoroughly explored. The contributions of various researchers towards the study of such work have been mentioned below.

The Integro-differential operator proved to be a good circular edge finder. A non-linear enhancement of this operator makes it more robust for detecting the inner boundary of the iris. Daugman uses an Integro-differential operator for segmenting the iris (53). It finds both inner and the outer boundaries of iris region. The outer boundaries are called limbic boundaries as well as the inner boundaries are referred as pupil boundaries. The parameters such as the centred and radius of the circular boundaries are being searched in the three dimensional parametric space in order to maximize the evaluation functions involved in the model. This algorithm achieves high performance in iris recognition. The main drawback of this algorithm is that, it suffers from heavy computation.

In order to perform personal authentication and also the verification, an automated iris recognition system has been examined by the biometrically based technology (54). This paper also defines the technical issues which are being formed while designing an iris recognition system. The technical issues involve in three parts 1) during image capturing in terms of image resolution and in the focus of image. By using extant system in which standard optics devices applied in order to provide solution to these issues. 2) Second issue is Iris localization. In image acquisition mode the size of captured image becomes very larger which contains iris as a part of it. The edge detection has been performed through the gradient-based Canny Edge Detector, which is followed by the Circular Hough Transform (CHT), which is used for iris localization. 3) The final issue is the pattern matching. After the localization of the region of the acquired image which corresponds to the iris, the final operation is to decide whether pattern matches with the previously saved iris pattern. This stage involves alignment, representation, goodness of match and also the decision. All these pattern matching approaches relies mainly on the method which are closely coupled to the recorded image intensities. One way to deal with this is the extraction as well as matching the sets of features that are estimated to be more vital to both photometric as well as geometric deformations in the obtained images. The advantage of this method is that it provides segmentation accuracy up to an extent. The drawback of this approach is that, it does not provide any attention to eyelid localization (EL), reflections, eyelashes, and shadows which is more important in the iris segmentation.

An EMD approach for extracting the residual components from the iris image as the features for recognition has been proposed by Jen-Chun Lee et al. They evaluated three diverse similarity measures. Hence, their proposed method was considered an encouraging method for iris recognition and for feature extraction for which EMD is suitable (55).

Miyazawa, K. Ito et al have phase components in 2D Discrete Fourier Transforms (DFTs) of given images in their algorithm for iris recognition which uses an image matching technique known as Phase-Based image matching. Their experimental results show that the use of phase components for iris images has made it possible to accomplish highly precise iris recognition even for low-quality iris images. The difficulty in designing a compact phase-based iris recognition algorithm especially suitable for hardware implementation has also been taken into consideration in their paper (56).

A technique proposed by Jen-Chun Lee et al for evaluating the iris signals locally known as Modified Empirical Mode Decomposition (MEMD) for iris recognition. As MEMD is a fully data-driven method, avoid of using any pre-determined filter or wavelet function, it has been considered as a low-pass filter for extracting the iris features for iris recognition. Three diverse similarity measures have been considered for assessing the efficiency of their proposed method. The outcomes of the experimental result show that the three metrics have accomplished potential and analogous performance. Hence, the proposed technique confirms the viable of it for iris recognition and MEMD is appropriate for feature extraction (57).

An algorithm has been proposed by Miyazawa, K. Ito et. al for iris recognition using phase-based image matching which is an image matching technique by employing phase components in 2D Discrete Fourier Transforms (DFTs) for given images. Experimental results obtained by using the CASIA Iris-v1 and Iris-v2 iris image databases and Iris challenge evaluation (ICE) 2005 database clearly illustrate that the use of phase components of iris images has made it feasible to accomplish highly precise iris recognition with a simple matching algorithm. They have also implemented it (58). The idea of 2D Fourier Phase Code (FPC) for representing iris information has been used to decrease the size of iris data and to avoid the visibility of iris images.

Munemoto et al. have suggested that “it is important to not only exclude the noise region, but also estimate the true texture patterns behind these occlusions. Even though masks are used for comparison of iris features, the features around masks are still affected by noise. This is because the response of filters near the boundary of the mask is affected by the noisy pixels.” They used an image-filling algorithm to estimate the texture behind the occlusions. This algorithm iteratively fills 9x9 patches of the occluded region with 9x9 patches from unoccluded iris that closely match the iris texture near the boundary of the area to be filled (59).

Ahmad M. Sarhan has given an approach for efficient iris recognition system. The design is based on the discrete cosine transform for feature extraction and artificial neural networks for classification. The used iris images in the system were obtained from the CASIA database. The robus iris recognition system was successfully designed at very low error rates (60).

Sandipan P Narote et al. have presented an iris recognition technique known as an inherently reliable technique for human identification. Feature extraction was a crucial and important step for iris recognition. The extracted features were used for matching. Different researchers used different wavelet transforms for feature extraction in iris recognition. Many researcher extracted features by using different coefficient such as horizontal, vertical, diagonal or combination of them. This system was used in SCOE-Iris v1 database consisting of 2750 images, available in the signal processing laboratory at Sinhgad College of Engineering, Pune, India. In their studies, wavelets were used for feature extraction and evaluated its performance also. The optimal wavelet transform was used. Experimental results show that this algorithm were efficient and provides acceptable accuracy (29).

Patnala S R Chandra Murthy et al. proposed an algorithm for automatic iris classification based on fractal dimensions by using Haar Wavelet Transforms. Fractal dimensions obtained from multiple scale features were used to characterize the textures completely. Haar Wavelet was applied in order to extract the multiple scale features at different resolutions from the iris images. Fractal dimensions were obtained from these patterns and a classifier was used to recognize the given image from a database. Performance was also studied among different classifiers (61).

S. Arivazhagan et. al have described an effectual multi-resolution based iris recognition system by which has high performance and less complexity. Pre-processing iris images, determining the pupil centre, transforming the iris boundary to the stretched polar coordinate system, removing the iris code based on texture analysis by employing multi-resolution transforms, such as Discrete Wavelet Transform (DWT), Double Density Wavelet Transform (DDWT) and Dual Tree Complex Wavelet Transform (DTCWT) have been considered in the system (62). A fast matching method which is on the basis of exclusive OR operation has been employed for categorization and calculating the similarity between a pair of position sequences in iris code.

Zhenan Sun and Tieniu Tan used a technique using ordinal measures for iris feature representation with the aim of embodying qualitative relationships between iris regions rather than exact dimensions of iris image structures. Such an illustration caused loss of some image-specific information, but it achieved a good trade-off between uniqueness and toughness. They presented that ordinal measures were intrinsic features of iris patterns and largely invariant because to the illumination changes. Besides, firmness and low computational complexity of ordinal measures resulted in highly efficient iris recognition (63). They used multi-lobe differential filters to calculate ordinal measures with flexible intra-lobe and inter-lobe parameters such as location, scale, orientation, and distance. Experiment performed on CASIA and UBIRIS iris image databases showed the efficiency of the proposed ordinal feature models.

Ryan N. Rakvic et al have proposed a more direct and parallel processing alternative using Field Programmable Gate Arrays (FPGAs), providing an opportunity to increase speed and potentially alter the form factor of the resulting system. Within this project, the most time-consuming operations of a modern iris recognition algorithm was deconstructed and directly parallelized. Furthermore, the parallel algorithm on FPGA also significantly outstripped the calculated theoretical best Intel CPU design. Lastly, on a state-of-the art FPGA, they settled that a full implementation of a very fast recognition algorithm was more than feasible, resulting in a potential small form-factor solution (64).

Chung-Chih Tsai et al have proposed a matching strategy with invariable characteristics which on the basis of the possibility fuzzy clustering algorithm matches a pair of local feature sets. Furthermore, an effective iris segmentation technique has been presented to identify the inner and outer boundaries of the iris from a gray-level image and segregate the annular iris region. For feature extraction, the Gabor Filters has been utilized to discover the local feature points from the segmented iris image that are present in the Cartesian coordinate system and create a rotation-invariant descriptor for each of the identified point. Moreover for comparing two sets of feature points and for calculating a similarity score for a pair of iris images, the proposed matching algorithm has been used. Experimental outcome has illustrated that the execution of the proposed approach is comparable to that of the well-known iris recognition systems (65).

H. Proenca proposed an iris segmentation algorithm to segment degraded iris images acquired in the visible wavelength. The algorithm is divided into two categories. The first part is detecting noise-free iris regions and second is parameterizing the iris shape. The first part is further subdivided into two sections: detecting the sclera and detecting the iris. This method is fast and able to adjust shapes with an arbitrary degree of freedom (66). This method is very accurate with noisy images that taken in visible wavelength, but this technique depend on sclera to determining the region of iris. The algorithm may fails when the sclera covered with dark colors caused by bad image picked environments or eye diseases.

A fast and accurate iris segmentation method has been given by C.Tan and A. Kumar. They have proposed reflection removal method in order to eliminate speculiarities from the input iris images and used an Adaboost-cascade detector technique for finding the iris part in the images and also to exclude the non iris image before the further processing. A pulling and pushing method has been used to properly localize the circular iris boundary (67). For the noncircular iris boundary, a cublic smoothing spline method has been taken. The rank filter and histogram filter has been applied to remove the noise due to eyelashes. The advantage of Pulling and Pushing (PP) method is the accuracy and speed. The drawback of this method is that the occurrence of the segmentation error.

Joseph Thompson et. al presented the effects of varying iris curvature dusring matching of test sample with stored templates. The lens of eye must change its shape to focus on objects at various distances. They have isolated the variable of iris curvature in the recognition process; implemented corneal model as experiment across images of wavering size of iris curvature and extended the iris surface constraint to allow for more general iris shape (68). This experiment showed that varying in size of iris curvature degraded matching performance.

Daugman proposed an iris code based algorithm for iris recognition uses the modified complex valued 2-D Gabor wavelets for feature extraction. By using simple Boolean Exclusive-OR operator, Hamming Distance (HD) has been calculated for matching. The value of HD equal to zero is obtained for the perfect match. Experimental outcome has illustrated nearby 99.9% accuracy and the execution time required for iris identification is less than one second (41, 43). The main drawback of this algorithm is that, it fails to handle noisy iris images.

Wildes has made use of an isotropic band-pass decomposition derived from application of Laplacian of Gaussian filters to the image data. Wildes also used the first derivative of image intensity to find the location of edges corresponding to the borders of the iris. It explicitly models the upper and lower eyelids with parabolic arcs. The results of the system proposed by Wildes were better than other techniques to identify the individuals in minimum time period (69).

Boashash and Boles proposed a new approach based on zero-crossings. This system firstly localized and normalized the iris by using edge detection. The zero-crossings of the wavelet transform are then calculated at various resolution levels over concentric circles on the iris. The resulting one dimensional (ID) signals are then compared with the model features using different dissimilarity function. This system can handle noisy conditions as well as variations in illumination. This algorithm is also translation, rotation and scale invariant (42, 70).

A. Edler proposed a new algorithm to extract the features of iris signals by Multi-resolution Independent Component Identification (M-ICA). It provides good properties to represent signals with time frequency. This extracts the iris features which are used for matching using conventional algorithms. The accuracy obtained is low because the M-ICA does not give good performance on class separability (71).

Li Ma et. al. have given a new approach based on circular symmetry filters to capture local texture information of the iris. This approach is further used to construct a fixed length feature vector. Nearest feature line method is used for iris matching. The results obtained were 0.01% for false match and 2.17% for false non-match rate (72, 73).

Chen and Yuan developed the algorithm for extracting the iris features based on fractal dimension. The iris zone is partitioned into small blocks in which the local fractal dimension features are computed as the iris code. And finally the patterns are matched using the K-Means and Neural Networks (74).

Wang *et. al.* proposed an algorithm based on Gabor filters and 2-D wavelet transforms for feature extraction. For identification weighted Euclidean distance classification has been used. This method is invariant to translation and rotation and tolerant to illumination (75).

Robert et. al. introduced new algorithm for localization and extraction of iris. For localization a combination of the Integro-Differential Operators with a Hough Transform is used and for feature extraction the concept of instantaneous phase or emergent frequency is used. Iris code is generated by thresholding both the models of emergent frequency and the real and imaginary parts of the instantaneous phase. Finally the matching is performed using Hamming distance (47).

Lim et. al. used Haar Wavelet transform to extract features from iris images. By applying the transform four times on image of size 450x60 and combining the features 87 bit feature vector was obtained. This feature vector is the compact representation of the iris image. Finally for classification of feature vectors, weight vector initialization and winner selection strategy has been used (76).

Machala et al proposed two new methods of the statistical and computer evaluations of the iris structure of a human eye in view of personal identification (77); which are based partly on the correlation analysis and partly on the median binary code of commensurable regions of digitized iris image. Similarly method of eye-iris structure characterization using statistical and spectral analysis of color iris images is considered in (78).

Gurianov et.al. (78) used Wiener spectra for characterization of iris patterns. In (79) human iris structure is explained and classified using coherent Fourier spectra of the optical transmission.

In (80), an efficient biometric security algorithm for iris recognition system with high performance and high confidence has been described. The system is based on an empirical analysis of the iris image and it is split in several steps using local image properties. The various steps are capturing iris patterns; determining the location of iris boundaries; converting the iris boundary to the stretched polar coordinate system; extracting the iris code based on texture analysis using wavelet transforms and classification of the iris code. The proposed system use the wavelet transforms for texture analysis, and it depends heavily on the knowledge of general structure of human iris. The system has been implemented and tested using a dataset of 240 samples of iris data with different contrast quality.

The noisy iris images increase the intra-individual variations, thus markedly degrading recognition accuracy.

Robert Szewczyk et. al. describes a reliable iris recognition algorithm based on reverse biorthogonal wavelet transform(81). This algorithm consist an iris code of 324 bits length, which is much smaller than the 2048-bit iris code used in the Daugman’s approach. They first considered a range of possible wavelet decompositions for use in analyzing the iris image. The difference between two 324-

bit iris codes resulting from this approach is computed as the fractional Hamming distance between the codes.

Peihua Li et. al., describes the algorithm that estimate an ellipse for the limbic boundary of the iris region, and observe that this gives a more accurate boundary than a circular Hough transform (82). A search was performed over a set of candidate 2D Gabor filters to select the particular ones to be used in creating the iris code. The proposed approach is compared to Daugman's 1993 algorithm (83) and found to perform better. However, Daugman's 1993 algorithm would not be expected to be competitive with today's state of the art; for example, it assumes circular limbic and pupillary boundaries.

Peihua Li et. al., also describes the algorithm in which the co-occurrence histogram considers the phase angle at a given pixel along with that of each pixel at a distance of *d* pixels from the given pixel (84). Experiments are conducted with a training set to select the values of important parameters of the approach. Based on these experiments, the value of *d* is set at 2. Based on the parameter tuning experiments, it appears that the performance of the method decreases quickly with *d* greater than 3. So the co-occurrence relations captured are fairly local in nature. Also, with phase angle divided into 6 bins, the feature vector is of length 62 = 36. Larger feature vectors did not result in any noticeable performance increase. The weighting aspect of the algorithm is that a pixel contributes to more than a single bin of the histogram, based on the difference between the phase value at the pixel and the range of near bins. The weighting factor is also tuned on the training set. The co-occurrence histogram is computed separately for each of a number of nonoverlapping regions of the iris, with the intention to provide some robustness to alignment problems.

Michele Nappi et. al., describes the algorithm with approach to iris texture matching combines local binary patterns (LBP) and discriminable textons, called "blobs" (85). They fit circles to the pupillary and limbic boundaries of the iris region and create a 40x360 rectangular iris image. The LBP and blob features are viewed as capturing complementary elements of the iris texture, with the LBP capturing "the textural regularities present in the iris, and blob identification for coding lighter or darker spots". The iris region is considered as having five horizontal bands and a LBP histogram is computed for each band. This sequence of five LBP histograms then effectively becomes an “iris code” for the iris, though not obtained as, or structured as, a Daugman-like code. Dark and light blobs are found using a Laplacian-of-Gaussian operator at different scales and binarizing the result. Thus the iris code obtained for the blob analysis has a spatial structure that is somewhat more Daugman-like than the code for the LBP analysis. The name LBP-BLOB is given to the fusion of the two approaches, done by averaging the two scores. Results show that the combination of the two approaches performs better than either alone, and that the most useful scale for the blob analysis is different if the blob analysis is used alone versus used in combination with the LBP analysis.

Kwang Yong Shin et. al., describes the algorithm. This approach employs an interesting sequence of classifier steps leading to a fusion of iris codes from the red, green and grayscale versions of the iris image (86). The first step uses cues from the eyelash distribution and specular reflections to classify the image as representing a left iris, a right iris, or undetermined. Eyelash density and specular reflection density both are generally greater near the medial canthus (corner of the eye near the nose) than near the latreal canthus (outer corner of the eye). Classification of the eye in the probe image is used to restrict the set of gallery images that are matched against. A second step uses differences between the two images’ iris region color distributions based on color spaces. The final step computes Hamming distances for iris codes based on each of the red and green color planes and the grayscale version of the image, and a weighted sum rule to fuse the distances. One interesting aspect of this approach is that its performance was good even though the left/right classification and color distribution classification steps sometimes made errors.

Gil Santos et. al., describes a fusion approach to unconstrained iris recognition. Their approach is a multi-biometric fusion of five component algorithms (87). Both 1D wavelet and 2D wavelet zero-crossing maps are used as representations of iris texture. Another representation of iris texture used is based on the typical iris code resulting from 2D Gabor filters, but viewed as a binary “map” of the image and analyzed in a “comparison map” approach involving 16 sub-regions. For information extracted from the ocular region around the iris, two types of features are used. One is an LBP representation of the texture, and the other is based on a scale-invariant feature transform (SIFT) points. A logistic regression approach is used to fuse the five component results. Experiments were done to verify that the fusion result performs better than any of the individual components. Of the individual components, the zero crossing based on 1D wavelets showed good performance, whereas the SIFT-based component showed the poorest performance.

Qi Wang et. al., describes an adaboost and multi-orientation 2D Gabor-based algorithm for accurate noisy iris recognition. They look at the concept of “noisy iris” partly in terms of whether or not the inner iris boundary is accurately detected. The authors observe that, with their approach to iris segmentation, the outer boundary is generally localized well, but that the inner boundary can still be difficult to distinguish and localize. This work uses the standard rubber-sheet transform in cases where the inner and our boundaries are both well detected, but uses a simpler rubber-sheet transform in cases where only the outer boundary is well detected. Part of the surprise in this work is that using a simplified rubber sheet transform based on only the outer iris boundary could lead to good performance. This work also considers iris codes generated for the whole iris and for local regions of the iris. The local regions are defined by considering top, right, bottom and left quadrants of the iris, and also either three or four concentric bands of the iris. Three bands are considered when both boundaries of the iris are used, and four bands are considered when only the outer boundary of the iris is used. Also, the Gabor filters are used at multiple orientations for the whole iris and for the local regions. Of the local regions considered, they find that features from the outer, lower region generally perform best. Features from regions of the iris nearest the pupil were not among the best-performing in either the case of a well-localized inner boundary or a not-well-localized inner boundary(88).

Tieniu Tan et. al.,proposed the algorithm based on multiple cues for noisy iris image matching (89). Their approach is distinguished from most of the approaches described above by being a strongly multi-biometric approach that exploits multiple sources of information available in both the iris region and the surrounding ocular region. They use two iris-based sources of information: iris texture representation using ordinal measures as previously described by the CASIA research group, and iris color based matching. They also use two ocular-based sources of information: a texton-based matching of skin texture in the ocular region, and “semantic information” based on geometrical asymmetry of the eyelash distribution. Fusion of the four sources of matching information is done using a weighted sum of scores. The use of two sources of ocular information is an especially interesting aspect of this paper, as ocular biometrics has recently become a hot topic. Even more interesting is the use of two different types of ocular information, including one based on the eyelashes.

Lye Wi Liam et. al proposed a system consisting of two parts: Localizing Iris and Iris Pattern Recognition (90). They used digital camera for capturing image; from the captured images Iris is extracted. Only the portion of selected Iris then reconstructed into rectangle format, from which Iris pattern is recognized.

Eric Sung et. al proposed a modified Kolmogora, complexity measure based on maximum Shannon entropy of wavelet packet reconstruction to quantify the iris information (91). Real-time eye-comer tracking, iris segmentation and feature extraction algorithms are implemented. Video images of the iris are captured by an ordinary camera with a zoom lens. Experiments are performed and the performances and analysis of iris code method and correlation method are described. Several useful findings were reached albeit from a small database. The iris codes are found to contain almost all the discriminating information. Correlation approach coupled with nearest neighbors classification outperforms the conventional thresholding method for iris recognition with degraded images.

Jiali Cui et. al have proposed the iris recognition algorithm based on PCA (Principal Component Analysis) is first introduced and then, iris image synthesis method is presented (92). The synthesis method first constructs coarse iris images with the given coefficients. Then, synthesized iris images are enhanced using super resolution. Through controlling the coefficients, they create many iris images with specified classes. Extensive experiments show that the synthesized iris images have satisfactory cluster and the synthesized iris databases can be very large.

Hyung Gu Lee et. al have introduced the invariant binary feature which is defined as iris key (93). Iris image variation is not important in their work. Iris key is generated by the reference pattern, which is designed as lattice structured image to represent a bit pattern of an individual. Reference pattern and Iris image are linked into filter. In the filter Iris texture is reflected according to the magnitude of iris power spectrum in frequency domain.

Zhenan Sun et. al proposed an algorithm to overcome the limitations of local feature based classifiers (LFC) (94). In addition, in order to recognize various iris images efficiently a novel cascading scheme is proposed to combine the LFC and an iris blob matcher. When the LFC is uncertain of its decision, poor quality iris images are usually involved in intra-class comparison. Then the iris blob matcher is resorted to determine the input iris identity because it is capable of recognizing noisy images. Extensive experimental results demonstrate that the cascaded classifiers significantly improve the system's accuracy with negligible extra computational cost.

Kazuyuki Miyazawa et al developed phase-based image matching algorithm (95). The use of phase components in 2D (two-dimensional) discrete Fourier transforms of iris images makes possible to achieve highly robust iris recognition in a unified fashion with a simple matching algorithm.

Pan Lili and Xie Mei, proposed a new iris localization algorithm, in which they adopted edge points detecting and curve fitting (96). After this, they set an integral iris image quality evaluation system that is necessary in the automatic iris recognition system.

Wang Jian-ming and Ding Run-tao proposed am iris image denoising algorithm, in which phase preserving principle is held to avoid corruption of iris texture features (97). Importance of phase information for iris image is shown by an experiment and the method to implement phase preserving by complex Gabor wavelets is explained. To verify the algorithm, white noise is added to iris images and Hamming distances between the iris images are calculated before and after the denoising algorithm are applied.

Weiki Yuan et. al have analyzed eye images that they have based on structure characteristics of eyes, they put forward a rapid iris location arithmetic (98). Firstly, they have got an approximative center by gray projection, have got two points that located at left and right boundary by threshold value respectively, and have got a point that located at the lower boundary by direction edge detection operators, then they ensured the boundary of pupil and probable center. Secondly, they have got exact pupil boundary and center by Hough transform that is processed at a small scope surrounding the probable center. Thirdly, they have searched two points that located at left and right boundaries between iris and sclera along horizontal direction by using the exact center and direction edge detection operators. Then they ensured the horizontal coordinate of the center of iris based on the above two point accurately. Finally, they have searched two points that located at upper and lower boundaries between iris and sclera beginning at the horizontal coordinate of the center of iris along the directions that making plus and minus thirty angles between horizontal direction respectively by using direction edge detection operators, so they ensured the coordinate of the center of iris and the boundary between iris and sclera. The experiments indicated that this method reached about zero point two second at speed and percentage of ninety nine point forty five at precision.

Christopher Boyce et. al examined the iris information represented in the visible and IR portion of the spectrum (99). It is hypothesized that, based on the color of the eye, different components of the iris are highlighted at multiple wavelengths. To this end, an acquisition procedure for obtaining coregistered multispectral iris images associated with the IR, Red, Green and Blue wavelengths of the electromagnetic spectrum, is first discussed. The components of the iris that are revealed in multiple spectral channels/wavelengths based on the color of the eye are studied. An adaptive histogram equalization scheme is invoked to enhance the iris structure. The performance of iris recognition across multiple wavelengths is next evaluated. They claimed the potential of using multispectral information to enhance the performance of iris recognition systems.

Chengqiang Liu Mei Xie, proposed Direct Linear Discriminant Analysis (DLDA) which combines with wavelet transform to extract iris feature (100). In their method, firstly, they apply wavelet decomposition to the normalized iris image whose size is 64×256 and just choose the coefficients of the approximation part of the second level wavelet decomposition to represent the iris image because this part contains main feature of the original iris image but the size of this part is only 16×64. And then make use of DLDA to extract the iris feature from this approximation part.

During classification, the Euclidean distance is applied to measure the similarity degree of two iris classes.

Hugo Proenca and Luis A. Alexandre analyzed the relationship between the size of the captured iris image and the overall recognition's accuracy (101). Further, they have identified the threshold for the sampling rate of the iris normalization process above that the error rates significantly increased.

An efficient technique on iris image acquisition, iris de-nosing, iris localization, and quality assessment have proposed by Kefeng FAN, Qingqi Pei, Wei MO, Xinhua Zhao, and Qifeng Sun (102). An automatic focusing system based on a decision function is introduced into the iris acquisition device to achieve the feedback control, which can capture the high resolution iris image with real-time. Iris localization differs from previous iris localization schemes in that it combines iris acquisition with edge detection technique. On the basis of coarse detection, the iris accurate detection is based on the combination of wavelet-based least square method, Laplacian of Gaussian function and an improved Hough Transform. They claimed that the technique has a good performance, which not only capture high quality iris image, but also improve the speed and accuracy or iris localization.

Boles and Boashash decomposes one-dimensional intensity signals computed on circles in the iris image to characterize the texture of the iris and use zero-crossings of the decomposed signals for the feature representation (103). Iris matching is based on two dissimilarity functions. The number of zero-crossings can differ among iris image samples of an identical iris due to noises. This method is improved in which it is assumed that if two samples are acquired from an identical iris, the distance between corresponding pairs of zero-crossing in one sample and the other is less than given threshold value. However, the spurious zero-crossing points can degrade the performance.

Kong and Zhang propose an eyelash and reflection segmentation in their algorithm (104). The overall system is developed based on the algorithm of Boles and Boashash with the addition of an eyelash and reflection segmentation model. The strong reflections are detected by setting a threshold for the intensity value, and the weak reflections are detected by using a statistical model on the intensity distribution (103). They tried four types of 1-D wavelets (Mexican hat, Haar wavelet, Shannon, and Gabor) to extract the iris features. In matching, the dissimilarity between a pair of iris codes is defined by L1 norm.

Kong and Zhang propose an algorithm that divides the problem into two possibilities (104); separable eyelashes and multiple eyelashes. Separable eyelashes are treated as edges. The image is convolved with a Gabor filter and thresholded to segment the eyelashes. Multiple eyelashes are modeled using an intensity variation model - eyelashes overlapping in a small area have a low intensity variation. If the variance of intensity (standard deviation) in the area is below a threshold, the center of the window is labeled an eyelash pixel.

Chen et al proposes the use of an “S-iris encoding” which is generated from the inner product of the output from a 1D Log Gabor filter and secret pseudorandom numbers (105). In the segmentation stage, first an edge map is generated using a Canny edge detector. A circular Hough transform is used to obtain the iris boundaries. Linear Hough transform is used in excluding the eyelid and eyelash noises. Then the isolated iris part is unwrapped into a rectangle using Daugman’s rubber sheet model. Then the final iris code is generated from the inner product of the output from a 1D Log Gabor filter and secret pseudo random numbers. In matching, Hamming distance is used to indicate the dissimilarity between a pair of iris codes.

Schmid et al proposes an algorithm to predict the iris biometrics system performance on a larger dataset based on the Gaussian model constructed from a smaller dataset (106). It analyzes the performance of Maseks System. In the matching stage, it uses a sequence of K iris codes to represent an iris subject. So the distance between a pair of iris subjects is defined as a K-dimensional Hamming distance, modeled as Gaussian distribution. The Gaussian models were constructed on the CASIA dataset (CASIA) and West Virginia University (WVU) dataset separately.

Tan et al describe an efficient algorithm for iris recognition by characterizing key local variations (107). This reduces the computational complexity. The basic idea is that local sharp variation points, denoting the appearing or vanishing of an important image structure, are utilized to represent the characteristics of the iris.

A large number of filter-based iris encoding algorithms have been designed over the past few years. These methods often demonstrate outstanding performance, especially on datasets of good image quality. In the iris recognition systems, the image quality is considered as a critical issue which directly affects the overall performance of identification process. Initially, image acquisition for iris biometrics required extremely controlled conditions. In order to extend the possible applications of iris biometrics, recent work has attempted to reduce the constraints required for image acquisition.

Non-cooperative behavior in an authentication system results in low quality captured images caused by user motions during the image acquisition process. So many proposed iris verification and identification systems assume that the iris images are taken under several controlled conditions such as properly arranged illumination and the cooperative behavior of person. However, when user cooperation is not available in applications such as automatic recognition and surveillance, it is not easy to obtain high quality iris images. The images may be blurred due to poor focus and have reflections due to different light sources and spectacles. The iris in the image may also be occluded by eyelashes and eyelids. Iris orientation, on the other hand, depends upon a large number of internal and external factors including torsional eye rotation and head tilt.

Huang et al identified four distinct types of noises such as eyelashes, eyelids, reflections and pupil. The basic idea is that there is always some type of edge between the noisy and the noise-free areas. All these edges were identified through an illumination invariant measure (phase congruency) (108).

Asheer et al approach the detection of eyelash occlusion using the gray-level co-occurrence matrix (GLCM) pattern analysis technique. The GLCM is computed for 21x21 windows of the image using the most significant 64 grey levels. A fuzzy C-means algorithm is used to cluster windows to form skin, eyelash, sclera, pupil, and iris based on features of the GLCM. There are no experimental results in the context of verification or recognition of identity. Choosing the correct window size is the challenge of this approach (109).

Zhu et al and Jaemin Kim et al propose the equalization of the histogram of the segmented and normalized iris image to reduce the effect of non-uniform illumination. They propose the utilization of morphological operators to detect isolated eyelashes (110,111).

Li Ma et al propose a global iris image enhancement by means of local histogram equalization and the removal of the high-frequency noise through Gaussian low-pass filtering (112).

Kazuyuki et al and Du et al propose the computation of the standard deviations within small windows. If the value is higher than a threshold, the central pixel of the window is considered as noise, providing the exact localization of each noise region within the image(113, 114).

Du et al investigate the performance of the use of a partial iris part for recognition. They analyzed 3 different kinds of partial iris images: “left-to-right” (left middle part of the iris), “outside-toinside” and “inside-to-outside” (respectively the outer and inner parts of the iris). In their experiments, the authors observed a distinguishable and unique signal when analyzing the inner parts of the iris and concluded that it is possible to use only portions of the iris for human identification (114).

Non-cooperative iris recognition (Hugo Proenca and Alexander 2006b) is defined as the process of automatic recognition of individuals using images of their irises captured at a distance and without requiring any active participation (115).

Eric Sung et al roughly identified the potential problems that must be overcome. They considered the problem of lighting conditions In order to identify the information degradation resultant from the noncooperative image capturing, especially on the acquisition of defocused images, the authors propose a method based on wavelet packet. Shannon entropy reconstruction is used for measuring the image information. The feature extraction was made through the classical convolution with a bank of complex-valued 2D Gabor filters. They concluded that the feature comparison by means of correlation and classification through the nearest neighbor produce better results (116).

Singh et al demonstrate the new challenges of iris recognition when extended to less cooperative situation and describe some initial work in this area. The authors propose a new and robust iris segmentation methodology based on the well-known fuzzy-clustering algorithm which yields high segmentation accuracy in noncooperative image acquisition (117).

Mehrotra et al proposed a new classification approach that minimizes the interference from different illumination sources and further detects the potential eye localizations through the use of support vector machines (118).

Dorairaj et al describe an iris recognition system that deals with off-angle images. Through the Hamming distance between the Independent Component Analysis of a frontal view image and the captured one they estimate the gaze direction, Further, they apply a projective transformation that brings the captured iris image to frontal view. Apart from images of the CASIA database, the authors use other images captured in their institute to experimentally confirm their conjectures and achieve high accuracy in the recognition of off-angle images (119).

Hugo Proenca and Alexandre extract the iris features using 2D Gabor filter and compute the merit of each feature. They select the higher discriminating features according to merit value for classification. They also consider the problem of noncooperative environment and use UBIRIS iris image for experimental validation. Their classification strategy is based on threshold method and the accuracy of the system depends on the threshold selection (120).

Mayank Vatsa et al consider the same problem of nonideal 32 iris images. Support-vector-machine-based learning algorithm is used to select the locally enhanced regions from each globally enhanced image and combines these good-quality regions to create a single high-quality iris image. Two distinct features are extracted from the high-quality iris image. The global textural feature is extracted using the 1-D log polar Gabor transform, and the local topological feature is extracted using Euler numbers. An intelligent fusion algorithm combines the textural and topological matching scores to further improve the iris recognition performance and reduce the false rejection rate. The verification and identification performance of the propose algorithms is validated and is compared with other algorithms using the CASIA and UBIRIS iris databases (121).

Cui et al also proposed iris localization using texture segmentation. First, they used the information of low frequency of wavelet transform of the iris image for pupil segmentation and localized the iris with a different integral operator. Then the upper eyelid is detected next to eyelash segmentation. Finally, the lower eyelid is localized using parabolic curve fitting, based on gray value segmentation (125).

Monro et al. present a novel iris coding algorithms based on differences of Discrete Cosine Transform (DCT) coefficients of overlapped angular patches from normalized iris image (134).

Tisse et al. proposed a segmentation method based on integro-differential operators with Hough transform. This approach reduces the computation time and excludes potential centers outside of the eye image. Eyelash and pupil noise were also not considered in this method (135).

Huang et al used a new noise removing approach based on the fusion of edge and region information. The whole procedure includes three steps: rough localization and normalization, edge information extraction based on phase congruency and the infusion of edge and region information (136) and proceeded to iris segmentation by simple filtering, edge detection and Hough transform. This method is specifically proposed for removing eyelash and pupil noises.

Considering the above mentioned methods, we can state the following interesting remarks:

• In almost all of these methods, inner and outer boundaries, eyelashes and eyelid are detected in different steps, causing a considerable increase in processing time of the system.

• Usually, the inner and outer boundaries are detected by circle fitting techniques. This is a source of error, since the iris boundaries are not exactly circles.

• The results of the circle fitting method are sensitive to the image rotation, particularly if the angular rotation of the input image is more than 10o.

• In noisy situations, the outer boundary of iris does not have sharp edges.

• After detecting iris boundaries, the resulted iris area is mapped into a size independent rectangular shape area.

It must be observed that most of the proposals with the exclusive purpose of noise localization are quite recent and this area deserves a lot of more attention from the research community, as an answer to the robustness demands. Based on the above described analysis, it is found and decided to focus the noise effect in the normalized image because the utilization of the captured image, which contains more information apart from the iris, will obviously tend to decrease the method's accuracy and increase its computational complexity.