CHAPTER I

INTRODUCTION

Due to the fast development of information and communication technology security is a major challenging issue in network and individual based systems. In the case of information security, the access control process has different approaches like passwords, pin, keys etc. The intruders crack the system process without difficulty. To improve the security, biometrics based system is a precious approach for nowadays. Biometrics is a measurable physical characteristics or personal behavioral trait asked to reorganize identify or verify the claimed identity. Fingerprint, Face, Hand geometry, Palm, Iris, Retina and Voice etc are the different class of biometrics. In this, Fingerprint based technology is successful, unique, cost effective, reliable, easy and highly authentic. When passwords are used for authentication the decision made is relatively straight on a probability. Biometrics is not secret. Any organization considering the use of biometric fingerprint needs to understand the impact when reaching a trust decision. The existing methodologies have some limitations to identify or verify the claimed fingerprints. Recognizing through fingerprint is still a challenging problem for researchers.

The challenging problem in a novel fingerprint recognition system is to understand the relative advantages and limitations of different approaches. The success of fingerprint recognition system will depend on the method which is used to combine the individual decisions or matching scores. With the increased prominence on security, there is growing and urgent need to identify human both locally and remotely on a routine basis. During process the fingerprint image is captured using a data acquisition device and the captured fingerprint image is not ready for processing. So, the captured fingerprint is preprocessed with the basic methods like noise removal and enhancement.
The existing noise removal algorithms are not optimal. In this research, the fingerprint image noises are removed using Contourlet noise removal algorithm. Once the noises are removed the fingerprint image is enhanced using higher level image processing algorithms to identify the features.

The first research contribution is based on SVD-Contourlet based Enhancement for the fingerprint image to extract the features through Fixed Size Templates and the matching using Baseline Matching. The next contribution is a core detection using Iterative Block Based Orientation method (IBBO) to detect the core with Fuzzy based Background Foreground Separation and also the Effective area Separation by Adaptive FCM Pyramid Model to get better recognition rate by the factors such as FAR, FRR and EER. The fingerprint recognition systems is to improve the matching score for different quality fingerprint images such as good, fair and poor. The captured Query image is verified with finger Database image to identify the legitimate user to accept it or reject it.

The main aim of our work deals with the performance study and analysis of various methods for fingerprint image recognition system and proposes an improvised new class of Fingerprint Recognition method. The proposed class of fingerprint recognition methods addresses some of the important limitations like low complexity and high rate of spurious and missing minutiae, identified during the performance study and analysis on the existing fingerprint recognition methods. The major contributions of this work over the existing methods are noise removal and fingerprint enhancement, by which separating the foreground and background images, effective area separation for feature extraction and core detection process with minimal occurrence of spurious minutiae and reduced ratio of missing minutiae of a fingerprint recognition system. The alignment of core is an important feature to identify the type for separating the class.
Finally all the features extracted and converted into fixed sized template for effective matching using baseline matching.

1.1 The Role of Image Processing

Image processing covers a vast area of scientific and engineering knowledge. It builds on a foundation of one and two-dimensional signal processing theory and overlaps with such disciplines as artificial intelligence (scene understanding), information theory (image coding), statistical pattern recognition (image classification), communication theory (image coding and transmission), and microelectronics (image sensors, image processing hardware). Broadly, image processing may be subdivided into the following categories: enhancement, restoration, coding, and understanding. The goal in the first three categories is to improve the pictorial information either in quality (for purposes of human interpretation) or in transmission efficiency. In the last category, the objective is to obtain a symbolic description of the scene, leading to autonomous machine reasoning and perception.

Image Processing [79] [80] and Analysis can be defined as the "act of examining images for the purpose of identifying objects and judging their significance". A major attraction of digital imaging is the ability to manipulate image and video information with the computer. Now a days Digital image processing is a very important component in many industrial and commercial applications and a core component of computer vision applications. Image processing techniques also provide the basic functional support for document image analysis and many other pattern recognition applications. In the field of image enhancement the captured fingerprint image is not ready for processing. Before processing some preprocessing techniques should be applied with the help of digital image processing methodology.
The basic preprocessing methods are used here for noise removal using Contourlet Transform. Then the noise free fingerprint image is enhanced through SVD-Contourlet enhancement scheme. The existing noise removal and enhancement methods are defined below.

1.2 Fingerprint Image De-noising

The performance of fingerprint recognition relies heavily on the quality of the fingerprint image during image equalization. However due to skin conditions (wet and dry), sensor noise, incorrect finger pressure, transmission and low quality fingerprint signifies the percentage of noises in the captured fingerprint image. Due to noise levels the fingerprint images automatically degrades the quality. Image de-noising [92] has been intensively studied both in image processing and in computer vision. To estimate the noise level from a fingerprint image, the de-noising algorithm can be more effective to reduce the noise level in all types of fingerprint images.

The fingerprint image affected by noise can be identified by the type of noise and the measure of the noise level. Normally the impulse noises are found to detect and remove using mathematical morphology [41], Fuzzy based algorithms [42], Adaptive median filter [40] and wavelet transform [43] approaches is used for noise removal.

1.2.1 Impulse Noise Removal Using Mathematical Morphology

Mathematical Morphology (MM) is a powerful tool in image processing. This algorithm is used to eliminate the impulsive noise and useless components generalized and ordinary morphological operators. The simple and efficient MM method to eliminate impulsive noise from the fingerprint images can be restricted to a minimum number of pixels. The performance of MM is mostly dependent on structuring elements (SE), but
finding an optimal SE is a difficult and nontrivial task. The noise removal process is not supported for highly corrupted images.

1.2.2 Impulse Noise Removal Using Fuzzy

Impulse noise removal using Fuzzy based approaches such as Detail-Preserving Filter Based on Type-2 Fuzzy Logic filter only observes the center pixel performance. The impulse noise filters based on soft computing methodologies [15] [16] [39], as well as several other nonlinear filters [17] that combine the desired properties of the aforementioned filters. These filters are usually more complex than the aforementioned median and the mean-based filters. All of these methods more or less have the undesirable property of blurring image details and texture during filtering due to the uncertainty introduced by noise.

1.2.3 Noise removal Adaptive Median Filter

In fingerprint image the noise level is high in poor quality image when compared with others such as good and fair. But the median filter based noise removal technique process to separate the noise-pixels and noise-free pixels are roughly divided into two classes. Each class has the threshold levels but not maintained. Noise removal using adaptive median filter approach is simple but the total error rate is high compare to other filtering methods.

1.2.4 De-noising using Wavelet transform

In the fingerprint images compared with other images it has lot of curve based ridges, but the wavelet based filtering technique to filter the images as square. This method captures the smooth contours which are seen as dominant feature in natural
images. Wavelet transform generates its outstanding to decrease the power of geometric smoothness of the contours. Wavelet Transforms work as square transforms. Wavelet transform can represent a smooth contour with higher number coefficients compared with other transform techniques.

1.3 Enhancement Methods

The robustness of the recognition system can be improved by incorporating an enhancement stage prior to feature extraction. Fingerprint image enhancement techniques are often employed to reduce the noise and to enhance the definition of ridges against valleys. The various methods used for enhancement are such as Bi-Histogram equalization [45], adaptive contrast enhancement [44], DWT and SVD based Contrast Enhancement [46].

1.3.1. Enhancement using Bi-Histogram Equalization

Contrast Enhancement using Bi-Histogram Equalization [45] consists of two stages. In the first stage, the large histogram bins are divided into sub-bins using neighborhood metrics. In the second stage, histogram of the original image is separated into two sub-histograms based on the mean of the histogram of the original image. In this method the sub-histograms are equalized independently using refined histogram equalization, which produces flatter histograms. It can not only preserve image brightness but also further enhances local contrast. To improve local contrast, we use a neighborhood metric that sorts pixels of the same intensity into different sub-bins by the intensity information of their neighboring pixels. In this method the resultant image histogram that is more flat than in other existing brightness-preserving methods and also the average execution time is very high.
1.3.2 Adaptive Contrast Enhancement

Adaptive Contrast Enhancement Methods with Brightness Preserving [44] method divides the histogram based on the median, and iteratively divides into the lower and upper sub-histograms, to produce a totally four sub-histograms. The separating points in the lower and upper sub-histograms are assigned to a new dynamic range and clipping process is implemented to each sub-histogram. Finally, the conventional HE is implemented. The second method is the extension of the Bi-Histogram Equalization Plateau Limit (BHEPL). This method segments the histogram of input image based on its mean value. Then, clipping process is implemented to each sub-histogram based on their median value. The adaptive contrast enhancement histogram equalization methods are applied in the fingerprint image enhancement. The intensity saturation problem arises due to the shifting of the original mean brightness. Moreover, the HE also leads to over-enhancement, which produces unnatural phenomena and noise amplifying to the enhanced images.

1.3.3. DWT and SVD based Contrast Enhancement

In Discrete Wavelet Transform (DWT) and Single Value Decomposition (SVD) based Contrast Enhancement [46] the input image decomposes into four frequencies-sub-bands by using Discrete Wavelet Transform and it estimates the singular value matrix and it reconstructs the enhanced image by applying inverse matrix. Single Value Decomposition (SVD) [81] of an image can be interpreted as orthogonal square matrices. Discrete Wavelet Transform is used to separate the input low contrast image into different frequency sub-bands, where the LL sub-band concentrates the illumination information. That is why the LL sub-band goes only through the SVE process, which preserves the high-frequency components (i.e., edges). Hence, after inverse Discrete
Wavelet Transform (IDWT), the resultant image will be sharper with good contrast. In this method Single Value Decomposition – Discrete Wavelet Transform is used for image equalization to deal with illumination problem.

1.4 Ridge and Valley separation algorithms

Separation of ridge and valley in good, fair and poor quality images is an important process in the fingerprint recognition system. The ridge and valley structure are segmented to improve the pattern of finger images. The segmentation results of the fingerprint images are with high quality, which means clear ridges-valleys alternative pattern and less noise contaminated, could be extremely well based on simple threshold methods. However, when the quality of fingerprint image degrades due to extremely dry, wet, the remaining previous left fingerprint and light pressure etc., the segmentation would become rather challenging, and lots of efforts have been taken to solve these problems. The background and foreground separation of a fingerprint image has different approaches such as strokes imaging system [48], Drainage Pattern Algorithm [51] and wavelet transform [50].

1.4.1 Strokes Imaging System

Segmentation of fingerprint using Strokes Imaging System [48] to separate the ridge and valley using Polarimetric Feature which is captured based on the polarimetric variance (Polvar). Polarimetric characteristic is another distinguishable feature which, besides reflecting light carries, provides potential way to enhance the contrast between background and foreground images as well as for ridges and valleys in accordance with fingerprint images. Strokes imaging techniques offer the distinct possibility of yielding images with higher inherent visual contrast than normal techniques in many cases of interest. In this approach the polarimetric features are not supported for orientation
estimation and enhancement. The parameters calculation could not get the complete information.

1.4.2 Drainage Pattern Algorithm

In the drainage pattern algorithm the ridges and valleys classify the characterizations as Local, Global and Multi local [51]. The drainage pattern algorithm first eliminated all the local minima and the planer areas to ensure the continuity of streamlines then the initial accumulation at each pixel was set to one. It would be difficult to obtain a continuous stream with high accumulation along the right coronary artery center. It is the most complex method in the case of fingerprint image separation.

1.4.3. Detecting Valley Using Wavelet transforms

Detecting the valley of fingerprint using Wavelet transforms and zone division method [50], to extract the valleys of fingerprints form a non-conduct visual input using wavelet transform and zone division before performing histogram equalization the luminosity ingredient of the input image. The edge is obtained by deleting the low-frequency from the divided signal group. Before performing the histogram equalization the luminosity ingredient of the image is calculated. In this approach interpolation processing of disconnection portions is not included.

1.5 Effective area separation procedures

In order to separate the fingerprint image effective area the important foundation process is to detect the approximate core area. It makes the core verification process as time consuming. In order to process the entire fingerprint image area only smaller area. In a fingerprint image the effective area is detected according to the image surface resolution approximation. The fingerprint effective area is separated using different
approaches such as threshold surface [53], Optimization based approach [55] and Gradient Vector Field [56].

1.5.1. Adaptive Threshold Surface

In Image Binarization [53] this method is to determine an adaptive threshold surface by multi-resolution approximation. The threshold surface is constructed with considerably lower computational complexity. This approach has smooth and faster image Binarization. Then the new threshold surface can be made smooth and nature of its construction should be similar to the local illumination level. These qualities allowed us to often obtain better visual performance of the Binarization process [84]. Over the entire image area the threshold surface has its operation only on relatively smaller region.

1.5.2. Optimization based approach

In the Optimization based approach [55] the Image Binarization is one of the main techniques for image segmentation. It segments an image into foreground and background objects. In this approach the image Binarization divides the pixels of an image into two regions with similar gray levels. It is similar to data clustering where data are partitioned into clusters with similar properties. This method compared with Otsu’s method [33] was developed in statistical point of view but optimization method from the viewpoint of data clustering. To apply this technique for poor quality fingerprint image it gives the unsatisfactory result.

1.5.3. Gradient Vector Field

In this method the fingerprint image is segmented using Gradient Vector Field [56] to separate the image with a gradient is a measure of change in a function, and an image can be considered to be an array of some continuous function of image
intensity. The gray values of an image can be detected by using a discrete approximation to the gradient. This method takes two prominent properties such as clarity of ridge to valley and slow change of fingerprint texture orientation. But the separated area has many noises, relatively it shows high contrast.

Image Binarization using Hybrid Thresholding [52] method is a hybrid color quantization process, which adaptively takes the global and local image characteristics. When only the textual feature is emphasized to extract, the picture feature is not carried at all in the output images.

1.6 Core detection methodologies

The most evident structural characteristic of a fingerprint is the pattern of interleaved ridges and valleys. Some parts of the ridge curves resemble semicircles, whose center is called a core. Core point detection is a non trivial task. To determine the location of the core point we first need to estimate the orientation field of the fingerprint. For the fingerprint identification and verification scheme, the alignment of core is very important to improve the matching score and reduce the searching time. To detect the exact core for the existing methodologies are Direction of Curvature Technique [57], Singular Candidate Method [58], Differences of the orientation values along a Circle (DORIC) [59] and Gradient based techniques [60].

1.6.1. Core Detection Using Direction of Curvature Technique

The core point detection has played an important role in most fingerprint identification technique. The quality of the acquired fingerprint images may vary in both the printed location and the clarity of the image. The Direction of curvature technique [57] the enhancement process, tries to level-up the image condition to the state
that it can be later processed with high degree of success. At this state noise could be removed by applying orientation-based filter. In this method the images are pre-processed with gray level enhancement [85] followed by the orientation estimation. The orientations of the arc type fingerprint do not change as fast for those when it is compared to other types. So this algorithm fails in locating the core point of the fingerprint with arc structure.

### 1.6.2. Singular Candidate Method Core Detection

In the exact core detection process using Singular Candidate Method [58] to detect the core by singular candidate analysis using an extended relational graph. It uses both the local and global features of the ridge direction patterns. Singular candidate analysis is adopted in the detection process; this analysis involves in the extraction of locations in which the probability of the existence of a singular point. In such cases the input fingerprint image is significantly degraded; it is quite difficult to precisely detect the core and delta.

### 1.6.3. Core Point Detection Using DORIC

The Differences of the orientation values along a Circle (DORIC) [59] approach is the singular point detection method based on differences of the orientation values along a circle feature and global constraints. The optimal singular points are chosen to minimize the difference between the detected orientation field and model-based orientation field reconstructed using the singular points [86] [87] [88]. In case of poor quality fingerprints the spurious detected points can heavily degrade the performance of this algorithm in many applications.
1.6.4. Orientation field using Gradient based techniques

The orientation field of the fingerprint which is calculated using Gradient based techniques [60] is based on orientation field of the fingerprint which is calculated using gradient based technique and optimized neighborhood averaging to generate a smoother orientation field. This method is operated as a specially designed mask for detecting core point as the orientation field in the region of the core point is differs than the other area. The loop structure is not present, only the curvature regions are prominent and also error in this algorithm is high. In the Poincare Index [110] based method also cannot detect the exact core point. In case of two stage algorithm [61] for core finding technique the first stage determines the existence of core point region and the second stage determines the actual core point by ridge components. It is clearly stated that the above algorithms are not supported efficiently for all types of fingerprint images in core detection.

1.7 Feature Extraction principles

The fingerprint features are extracted using directional filter bank-based [62] method. It used to decompose the fingerprint image into eight directional sub-band outputs using a directional filter bank (DFB). The directional energy distributions of the each block are decomposed as sub-band outputs. Only dominant directional energy components are employed as elements of the input feature vector, which serves to reduce noise and improve efficiency. For the rotational alignment, additional input feature vectors are added in which various rotations are considered and extracted. These input feature vectors are compared with the enrolled template feature vector. This method significantly reduces the memory cost and processing time associated with verification, primarily because of the efficient DFB structure [89] [90] and the exploitation of directional specific information.
Local Features for Enhancement and Minutiae Extraction in Fingerprints [63] the parabolic symmetry is added to the local fingerprint model which allows to accurately detecting the position and direction of a minutia simultaneously. The extraction which does not require explicit thinning or other morphological operations constitute a robust alternative to conventional minutiae extraction [64] [65]. All necessary image processing is done in the spatial domain using 1-D filters only. This algorithm is more difficult to extract the fingerprint features and also it does not give an account of performance with rolled fingerprints.

Minutiae Extraction in Fingerprint using Gabor Filter Enhancement [66] algorithm is proposed for minutiae feature extraction and post processing. A global feature extraction [82] and fingerprints enhancement are based on Hong enhancement method which is simultaneously able to extract the local ridge orientation and ridge frequency.

1.8 Matching techniques

The fingerprint matching using Global Comprehensive Similarity [77] is based on the global comprehensive similarity with three steps. Such as similarity measurement and parameter estimation, grouped according to their affinity with a ridge and the relationship between transformation and the comprehensive similarity between two fingerprints. In this approach the quality of fingerprints affects the reliability of minutiae, rotation parameter, center points, and, therefore, affects matching performance [29] [30].

Alignment-Free Cancelable Fingerprint Templates Based on Local Minutiae Information [68] for making cancelable fingerprint templates that do not require alignment. For each minutia, a rotation and translation invariant value is computed from the orientation information of neighboring local regions around the minutia. The
invariant value is used as the input for two changing functions that the output values for
the translational and rotational movements of the original minutia, respectively, in the
cancelable template. When a template is compromised, it is replaced by a new one
generated by different changing functions. This approach preserves the original
geometric relationships (translation and rotation) between the enrolled and query
templates after they are transformed. Therefore, the transformed templates can be used to
verify a person without requiring alignment of the input fingerprint images.

If we can extract an ideal invariant value, the same minutia will yield the same
invariant values although fingerprint images are changed. In this case, the methodology
degrades performance because the geometric relationships among the original fingerprint
templates are preserved in the transformed fingerprint templates. However, it is expected
that errors will occur when obtaining the invariant values in practice.

The above existing methods motivates and improves the information security [2]
using biometric [1] [12] based recognition system with highly authentication [23].
Fingerprint [11], Face [4] [5] [7], Hand geometry [9], Palm [8] [10],
Iris [13], Retina [13] and Voice [14] are the different biometric technologies. Fingerprint
recognition [3] [21] [22] based technology is a successful, unique [19] [20], cost
effective, reliable, easy and highly authentic.

The fingerprint features are extracted [6] [24] through the higher level image
processing algorithms and classification [25] [26] [27] [28] using pattern recognition
methods.