CHAPTER 4

Fingerprint Recognition System

The requirement of an Automatic Fingerprint Recognition System over the conventional method is discussed in Chapter 3. The Automatic Fingerprint Recognition System requires several processing stages, to identify an unknown fingerprint image. Each and every processing stage in the system has its own contribution to make an accurate match or a miss match. Fingerprint identification or verification process is highly dependent on the enhancement stage and feature extraction stage. If the undesired noise, which contributes to the false minutiae, is removed in the enhancement stage and only genuine minutiae are extracted during the feature extraction stage than the matching accuracy, for personal identification, is better, but in practice it is not possible due to the presence of noise which makes false minutiae even after enhancement.

4.1 Previous Systems

Some of the fingerprint identification systems proposed by different authors are discussed in this section. In 1998, Hong [46] proposed the design of the fingerprint recognition model into two different levels: System level and Algorithm level. The major issues at the system level design may be considered as i) what type of biometrics should be used, ii) selection of operational mode, iii) how to acquire a raw digital representation of the biometric characteristic, iv) the system architecture and v) other issues like ergonomics, physical size, power supply,

weight, cost, administrative and maintenance costs and environmental influence. The System level design also focuses on false acceptance rate and false rejection rate. Like, in some forensic applications, the criminal identification, it is the false rejection rate that is the major concern and not the false acceptance rate and on the other extreme, peoples are facing inconvenience due to high false rejection rate in a highly secured access control application, as their main objective is to deterring impostors. In between them, several applications are needed to be considered. The algorithm level design tasks are feature extraction and matching.

Tsai-Yang [50] in the year 2005, proposed a secondary feature which can be used in partial fingerprint matching. The author developed two matching scenarios:

a) If both the numbers of minutiae on input fingerprint and template fingerprint are less than the predefined threshold minutiae value ∞ or either one of them than, is less than the threshold minutiae value ∞ than brute force matching technique is used.
b) If both input fingerprint and template fingerprint contain more than the predefine threshold minutiae value ∞ than secondary feature based matching method is used.

In 2005, Raymond [51] proposed an algorithm for fingerprint identification system. The author divided the system into two parts: fingerprint image enhancement and feature extraction. Image enhancement and feature extraction consist of several stages.

In image enhancement, the different stages are as follows:

a) **Segmentation**: The first step of the fingerprint enhancement algorithm proposed by the Raymond Thai is image segmentation. A method based on the variance threshold is used for segmentation.
b) **Normalization**: Normalization is the process where the intensity values in an image can be standardised by adjusting the gray level so that the values lies within the desired range.
c) **Orientation estimation**: The least mean square estimation method is used to compute the image orientation.
d) **Ridge frequency estimation**: The first step in the frequency estimation stage is to divide the image into blocks of size W x W. The next step is to project the gray-level values of

all the pixels located inside each block along a direction orthogonal to the local ridge orientation.

e) **Gabor filter**: For a 2D Gabor filter enhancement, it used a frequency and a sinusoidal plane wave of a particular orientation.
f) **Binarization**: Binarization of the image is performed by using a global threshold of zero.
g) **Thinning**: Thinning algorithm is available in MATLAB bwmorph function as 'thin'.

And feature extraction consists of two stages:

a) **Minutiae extraction**: The Crossing Number is used for minutiae extraction.
b) **Erroneous Feature elimination**: In order to eliminate false minutiae, the validation algorithm proposed by Tico and Kuosmanen [47] is used.

Chikkerur [52] developed a fingerprint recognition algorithm using Short Time Fourier Transformation (STFT) in 2005. The algorithm consists of several stages like ridge orientation, ridge frequency, region mask, enhancement, feature extraction and fingerprint matching.

a) **Ridge orientation**: Ridge orientation is calculated by assuming the orientation 'θ', a random variable that has the probability density function p(θ). The expected value of the orientation may then be obtained by performing a vector averaging.
b) **Ridge Frequency**: Ridge frequency also calculated similar to the ridge orientation.
c) **Region mask**: Region mask is done by using Otsu's optimal threshold [48].
d) **Enhancement**: Fingerprint enhancement has two stages. The first stage consists of STFT analysis and the second stage performs the contextual filtering.
e) **Feature extraction**: Feature extraction is done by using Chain Code Contour.
f) **Fingerprint matching**: Fingerprint matching is done by using Graph Based matching.

Chaohong [49] in the year 2007, proposed an automatic fingerprint recognition algorithm with different stages.

a) A novel method for fingerprint image quality classification: The author has classified the fingerprints into five levels, according to the quality of the input fingerprint.

   Level 1- The fingerprints with clear ridge/valley contrast (good), easily- detected ridges, precisely-located minutiae and easily-segmented fall under this category.

Level 2- In these fingerprints, the contrast between the ridge and valley is medium, fair number of minutiae, possesses some poor quality blocks (dry or smudge).

Level 3- Ridge are not well separated because of Smudge/Wet.

Level 4- In dry or lightly inked image, only a small part of the ridge is appeared as it contains lots of broken ridges.

Level 5- Totally corrupted or spoiled, no sign for ridges.

b) Fingerprint Segmentation is performed by using Harris corner point feature to discriminate between foreground and background.

c) Enhancement of fingerprint based on the integration of the Anisotropic Filter and the Directional Median Filter (DMF). Gaussian-distributed noises are reduced effectively by Anisotropic Filter, whereas "impulse noises" are reduced efficiently by DMF.

d) Chain coded contour tracing algorithm is used for feature extraction.

The fingerprint recognition systems which are discussed above are not robust against rotation. The proposed fingerprint matching algorithm is rotation invariance as the comparison is based on MinHeap. Some of the advantages of proposed algorithm are early detection of two different fingerprints and image size with certain degree cannot affect the matching algorithm.

4.2 Proposed Fingerprint Recognition System

The primary focus of the proposed work is on the fingerprint enhancement, fingerprint matching, and the fingerprint database indexing. In order to make more effective recognition system, a multi stage processing system is proposed. The algorithm is broadly divided into three parts like preprocessing and post processing stage, heap based fingerprint matching and lastly, fingerprint database indexing. The proposed system is shown in the figure 4.1. The input fingerprint image is processed for enhancement and minutiae extraction by the preprocessing and post processing stage, constructs a distance feature for heap based fingerprint matching and to extract a set of records from template database is performed by indexing technique based on distance feature.

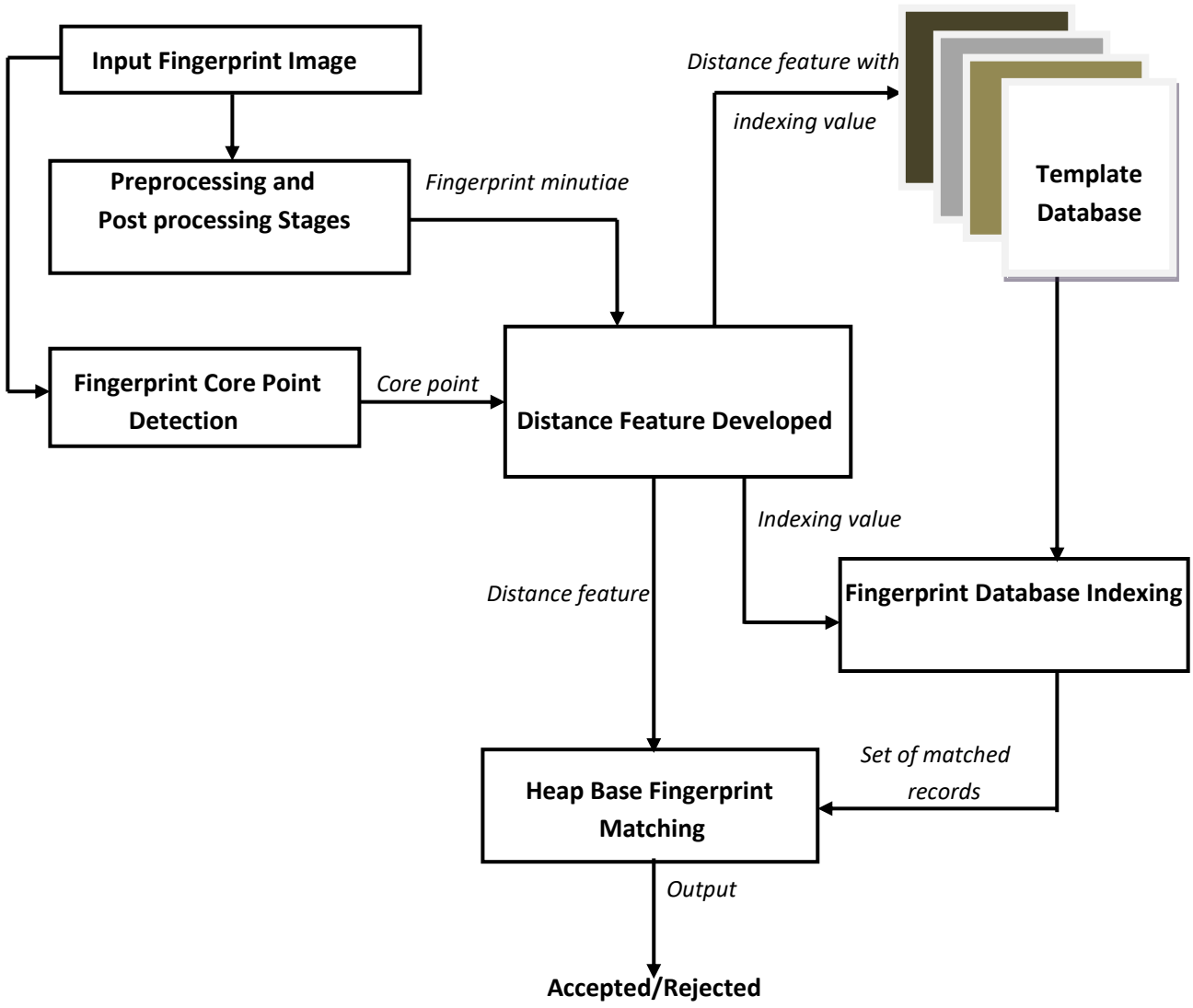

Figure 4.1 Proposed Fingerprint Recognition System

4.2.1 Preprocessing and post processing stages

In this section, a new fingerprint enhancement algorithm which used FFT and Gaussian filter is introduced. FFT is applied to a block, of size 32x32 pixel and Gaussian filter is applied in each interconnection of each block. This makes ridge smoothness and also reduce the "hairy" structure in the ridge when it is thinning. The experimental result shows that the implementation of FFT and Gaussian filter in the preprocessing stage makes less effort in the post processing stage and hence the total error rate of the proposed algorithm is very low. The details of the each part are discussed in chapter 5.

4.2.2 Construction of distance features

Distance features are calculated from the core point (X_c, Y_c) and fingerprint minutiae. The Euclidean distances from the core [68] to minutiae are distance feature. The details of distance feature are discussed in Chapter 6.

4.2.3 Heap based fingerprint matching

A novel fingerprint matching algorithm using MinHeap and Euclidean distance between the core point and minutiae points is introduced. In this algorithm, comparison is made between the MinHeap nodes, which are constructed from the two fingerprint images. The comparison is made at the root node of the MinHeap. After comparison, heapify operation performs as the root node deleted after comparison. The similarity level of the proposed algorithm is calculated by hit count. It also considers error tolerance, ϵ. The detail of matching is discussed in Chapter 6.

4.2.4 Fingerprint registration and fingerprint template database

Fingerprint registration is to store the records or information in a fingerprint template for further individual verification or identification after preprocessing and post processing stage. Fingerprint templates are collected with a fingerprint scanner and enrolled into the available fingerprint image database. The term 'template' is used to represent the stored file. Only the "template" is stored in the database when it entered into it, not an image of the fingerprint [53]. The details are discussed in Chapter 7.

4.2.5 Fingerprint database indexing

Indexing in large database is a challenging problem as it reduces the number of comparisons. Indexing selects a set of candidates for comparison among the large database. This section presents a new way of fingerprint database indexing technique. It is based on the distance feature from core to minutiae. It performs consistently from image distortion to rotation invariance. It requires less space as it deals only with a numerical value and also considers error tolerance ‘k’ as the fingerprint has elastic properties. The experimentation is done on FVC 2002 dataset. The high hit rate achieved at a low penetration rate indicates that the proposed distance feature indexing technique is satisfactory. The details are discussed in Chapter 7.

4.3 Chapter Summary

This chapter discusses the fingerprint recognition algorithms as available in the literature. The proposed model with different stages is explained. The fingerprint matching and data template are also discussed here.