CHAPTER 2

Literature Review

2.1 Scan Fingerprint Image

One of the important stages of the fingerprint recognition system is a fingerprint enhancement and minutiae extraction. Fingerprint enhancement is different from the general image enhancement method. Lots of fingerprint enhancement algorithm has been proposed in the literature, with an aim to improve the minutiae structure. Gorman and Nickerson [8] have proposed different filters for the fingerprint image enhancement and based on the local ridge orientation the coefficients mask k X k are generated. The four model parameters, derived from ridge width (W_{max}, W_{min}), valley width ($\bar{\acute{W}}_{max}$, $\bar{\acute{W}}_{min}$) and the fingerprint is describe by using minimum radius of curvature. It is assumed that the $W_{max} + W_{min} = \bar{\acute{W}}_{max} + \bar{\acute{W}}_{min}$. The mask is convoled with the input image. The enhanced image is binarized and post processing for fingerprint identification.

Mehtre[9] described a directional image of 16 X 16 pixel block and computed local gray level intensity variance along eight directions. The desired least direction is the direction which has least variance. The foreground and background of the fingerprint image is segmented by using local adaptive threshold and a Crossing Number (CN) is used for minutiae extraction. Sherlock et. al. [10] described a directional Fourier filter for the fingerprint image which used the information from the entire image, instead of a small neighborhood of the filtered point. The enhancement has two stages, like filtering stage and threshold stage. The filtering stage is for producing a directional smooth image by removing the noise from the input image and threshold stage is for converting the gray scale enhanced image in to binary image.

Hong et. al. [11] have taken advantage of the Gabor filter[12] frequency selective and orientation selective properties, to introduce a fingerprint enhancement algorithm, with a set of band pass filters, to remove the noise and preserve the true ridge and furrow structures. Hong et. al. [13] developed a fast enhancement algorithm, suitable for online fingerprint verification system. The algorithm finds the input fingerprint image into three regions as a well defined region, a recoverable corrupted region and an unrecoverable corrupted region and the Gabor filter is applied, only on the first two regions for enhancement and simply discarded the unrecoverable corrupted region. Hong et. al. [11] have used the traditional Gabor filter, assuming the ridge orientation as a sinusoidal plan wave, for enhancement. Yang et. al. [14] have modified the traditional Gabor filter with the parameter selection process, independent of the input fingerprint image.

Xiao and Raafat [15] considered the skeleton image as an input image and proposed an algorithm which identifies spurious minutiae and eliminates using the structural definition of the minutiae. The spurious minutiae are identified by using ridge width and ridge attributes like ridge direction, ridge length and minutiae direction. Hung [16] used Baja's algorithm to obtained a skeleton fingerprint image. The false minutiae are eliminated by evaluating the statistical parameters within an M X M matrix. Chen and Kuo [17] adopt a three-step false minutiae identification and elimination process like: (i) ridge breaks are repaired, using the ridge directions close to the minutiae; (ii) minutiae associated with short ridges are dropped; (iii) crowded minutiae in a noisy region are dropped. Some of the postprocessing algorithms [9, 18] eliminate the false minutiae by evaluating the statistical characteristics within an M x M matrix moving along the image pixel by pixel.

Stosz and Alyea [19] used pore positions coupled to other minutiae extracted from live scanned images: the quality of the valley skeleton is first improved by analyzing and extracting segments that represent pores (cleaning), then syntactic processing is used to remove undesirable artifacts: two disconnected ridges are connected if their distance is less than a given threshold and endpoint directions are almost the same; wrinkles are detected by analyzing information on neighboring branch points. Malleswara's methods [20] are used to eliminate those false minutiae which are caused by noise or imperfect image processing. A post-processing algorithm applied to binarized and not thinned images is proposed by Fitz and Green [21]. These techniques are employed to remove small holes, breaks and lines in and along the ridges and they are implemented by convolving morphological operations with the image. Spikes caused by the skeletonizing process can be removed by the adaptive morphological filter proposed by Ratha et al. [22]. Minutiae are detected by counting the BLACK neighbours in a 3 x 3 window. False Endpoints and bifurcations are removed by means of three heuristic criteria: (i) two endpoints with the same orientation and whose distance is below a threshold are deleted (ridge break elimination); (ii) an endpoint connected to a bifurcation and below a certain threshold distance is removed (spike elimination); (iii) minutiae below a certain distance from the boundary of the foreground region are cancelled (boundary effect treatment).Latent fingerprint enhancement and feature extraction is a challenging problem as the quality of the latent fingerprint is very poor.

2.2 Latent Fingerprint Image

Teddy [23] described the latent finger print image enhancement using spectral analysis technique. The latent fingerprints are often blurred, incomplete, degraded and their spatial definition is not clear and Teddy has presented a technique from frequency (spectral) analysis that can be used for the enhancement and restoration of degraded, noisy and sometimes incomplete fingerprint by using high-pass Butterworth filter and/or band-pass Butterworth filter. Rolled or flat fingerprint captured using ink or live scan instruments usually need only the spatial filtering techniques, such as brightness, contrast, gamma, and/or color map adjustment to examine the minutiae information. However, for latent fingerprints, besides the spatial image enhancement filtering, it need to use frequency (spectral) analysis techniques or combination of both spatial and frequency enhancement techniques to isolate and enhance the degraded and often very weak fingerprint information from variety of background patterns.

Jain and Feng [24] proposed a latent-to-rolled/plain matching algorithm which utilizes minutiae, reference points (core, delta, and center point of reference), overall image characteristic (ridge quality map, ridge flow map, and ridge wavelength map), and skeleton (or skeletonized image). These features are chosen due to their distinctiveness, repeatability, universality, and detectibility in 500 ppi fingerprint images. The features are manually marked for latents, but features for rolled prints are automatically extracted. Zhao et al. [38] proposed a new high resolution fingerprint identification system. It is suitable for full size fingerprint image and partial fingerprint image. The authors proposed a new fingerprints algorithm based on pores, a type of fingerprint fine ridge features that are abundant on even small fingerprint areas. Pores are first extracted by using a difference of Gaussian filtering approach. And a novel PVD-based coarse-to-fine pore matching algorithm is proposed.

Zhao et al. [39] proposed an algorithm for level 3 features which used in latent fingerprint. The level 3 features includes pores, dot, incipient ridges and ridge edge protrusion which are suitable for small size image like latent fingerprint image. The authors proposed an algorithm for extracting and matching several level 3 features. Yoon et al. [40] studied an AFIS system for ensuring that this system is not compromised for fake fingerprint. The authors classify the altered fingerprint into three types: obliteration, distortion and imitation. The authors developed a technique of automatic detection of altered fingerprint based on analyzing orientation field and minutiae distribution. Feng et. al. [41] proposed an altered fingerprint detection algorithm based on analyzing the ridge orientation field. The author used both real world altered fingerprint and synthetic generated altered fingerprint for experimentation. At a false alarm rate of 7%, their proposed algorithm detected 92% of the altered fingerprints, while NFIQ only detected 20% of the altered fingerprints.

2.3 Fingerprint Matching

Fingerprint matching is also one of the main stages of fingerprint recognition system. Different types of features are used for fingerprint matching. Some are like minutiae, correlation and pattern are used for fingerprint matching [56]. David[55] proposed a graph-matching algorithm using graduated assignment for fingerprint matching. A hybrid fingerprint matching algorithm is proposed by Jain et. al.[57] which used both minutiae points and texture information in local region. Gabriel et. al.[58] proposed a correlation coefficiency fingerprint matching algorithm using distance feature. Subhas et. al.[59] proposed a fingerprint matching based on distance information of minutiae point and to speed up the matching process, indexing technique is used. Feng et. al.[60] proposed a ridge and minutiae correspondences based fingerprint matching algorithm. The N initial substructures found in the novel alignment are used for fingerprint matching. A minutiae based fingerprint matching algorithm using local structure are proposed by Andrej et. al.[61]. The local structure characteristic is rotation and translation invariance, tolerance of deformations and fast and easy comparison.

Ito et. al.[62], proposed a matching algorithm based on phase-only correlation. The algorithm is invariant to shift, brightness and noise. Ning et. al.[63] proposed a Delaunay Triangulation based matching algorithm. It used co-ordinates and orientation of the minutiae point. Asker and Sabih[64] proposed a fingerprint matching algorithm based on elastic minutiae using a non-linear transformation model. The non-linear transformation model has two stages: the global matching which uses the possible correspondences to estimate a global non-rigid transformation and local matching based on local similarity measurement. A fingerprint matching algorithm based on local phase and global phase spectra is proposed by Karthik[65]. The fusion of the global and local similarity score is used for fingerprint matching.

A fingerprint matching algorithm based on minutiae using the adjacent feature vector is proposed by Xifeng et.al.[66]. The Adjacent Feature Vector consists of four adjacent relative orientations and six ridge count of a minutiae. A fingerprint matching based on genetic algorithm is proposed by Xuejun and Bir[67]. The fitness function for genetic algorithm is based on the properties of minutiae such as minutiae density, ridge count, traingle handedness and traingle direction. Weiguo et.al.[69] proposed a memetic fingerprint matching using genetic algorithm. The algorithm identifies the optimal and near optimal minutiae for fingerprint matching. Minutiae descriptor is used as a local feature which contain orientation and circular region around the minutiae point.

Table 2.1 shows the type of fingerprint matching found in the literature.

2.4 Fingerprint Indexing

Fingerprint database indexing is the other main stage of fingerprint recognition system. Database indexing is used to reduce the matching time. Some of the indexing methods which are available in the literature are discussed here. Guoqiang et. al.[72] proposed a feature extraction method based on minutia information to create a binary template. By using this binary template and Locality Sensitive Hashing indexing algorithm, a fingerprint indexing is designed. Tong et. al.[73], proposed an indexing method called local axial symmetry (LAS) based on fingerprint registration with a novel feature. After the LAS field is achieved, the location and direction estimation of reference point are achieved in a straightforward way. Then the registered orientation field is utilized as a feature vector to perform the indexing. Jianjiang and Anni[74] proposed an invariant-based fingerprint indexing scheme. A substructure is formed by combining Minutia and surrounding ridges. The binary relations between substructures are described by the invariants.

Tong et. al.[75] proposed a continuous fingerprint singular points. By applying a T-shape model to directional field of fingerprint images, location and direction estimation are achieved simultaneously. Homocentric sectors around the candidate singular points are analyzed by the T-shape model, to find the lateral-axes and further main-axes. Akhil and Anoop[76] proposed a hash-based indexing method to speed up fingerprint identification in large databases. . For each minutia, the features defined based on the geometric arrangements of its neighboring minutiae points are computed with its local neighborhood information. The features used are provably

Table 2.1 Types of some fingerprint matching algorithm found in the literature

Year	Reference	Feature	Method
1997	Jain et. al. [26]	Minutiae	Alignment-based elastic matching
2001	Jain et. al. [57]	Minutiae and Texture	Hybrid matching
2002	Asker and Sahid [64]	Minutiae	Thin plate spline model
2005	Ning et. al. [63]	Minutiae	Delaunay triangulation
2005	Xifeng et. al. [66]	Minutiae	Adjacent feature vector matching
2006	Feng et.al. [60]	Ridge and minutiae	Alignment method
2006	Xuejun and Bir [67]	Minutiae	Genetic algorithm
2007	Chandrasekaran and Thuraisingham [56]	Minutiae	Tree comparison using ratios of relational distance
2007	Seng et.al. [69]	Minutiae set	Memetic matching algorithm
2007	Tulyakov et.al. [90]	Minutiae	Symmetric hash function
2008	Andrej et.al. [61]	Local structure defined by minutiae and its neighbouring minutiae point	Local matching
2009	Shi and Govindaraju [70]	Feature vector	Euclidean distance between pairs of corresponding feature vector
2012	Karthik [65]	Minutiae	Phase spectrum
2014	Subhas et.al. [59]	Spacial information of minutiae point	X
2014	Gabriel [58]	Distance between the minutiae and core point	Pattern matching

invariant to translation, rotation, scale and shear. These features are used to create an arrangement vector (affine invariant local descriptor) for each minutia.

Singh et. al.[77] proposed level-2 and level-3 feature based fingerprint indexing algorithm to improve the speed and accuracy of identification Using the minutia and pore features, indexing parameters are computed. By incorporating Dempster Shafer theory based match score fusion algorithm, the identification performance is further improved. Xuefeng et. al.[78] proposed an algorithm which used novel features, formed by the Delaunay triangulation of minutiae set as the representation unit, which are insensitive to distortion. These novel features include minutia detail and Delaunay triangle (its handedness, angles, maximum edges, and related angle between orientation field and edges). Uysal and Gorgunoglu[79] proposed a method for fingerprint indexing by using ridge pattern. The ridge pattern within a triangular area is suitable to use as an index and very robust to elastic distortion and is represented by a numerical value.

Johan et. al.[80] proposed indexing method which extracts features that have the smallest feature distance to the query fingerprint. Modern systems are able to search databases up to a few hundred fingerprints by using this indexing method. The Three possible fingerprint indexing features viz, Registered directional field estimate, FingerCode and Minutiae triplets, are discussed in this method. Ogechulwu et. al.[81] proposed a method for indexing fingerprints named as “minutiae quadruplet”. It is used to filter a fingerprint database by combining with a clustering technique. Lalhmingliana et. al.[82] proposed a fingerprint indexing method based on graph information of minutiae, fingerprint classification and verification which use hierarchical agglomerative clustering technique. This fingerprint indexing is invariant under translation and rotation. Alessandra et. al.[83] proposed an indexing technique, primarily for latents, that combines multiple level 1 and level 2 features to filter out a large portion of the background database while maintaining the latent matching accuracy.

Table 2.2 shows the type of some indexing technique found in the literature.

Table 2.2 Types of some fingerprint indexing technique found in the literature

Year	Reference	Indexing feature	Method
2001	Johan et.al. [80]	Multiple feature: Directional field estimate, finger code and minutiae triplets.	X
2005	Tong et.al. [75]	Singular point	Correlation based similarity measured
2006	Tong et.al. [73]	Local axial symmetric	X
2006	Jianjiang and Anni [74]	Substructure formed by minutiae and surrounding ridge	X
2007	Xuefeng [78]	Minutiae neighbourhood structure and low-order Delaunay triangles	X
2009	Singh et.al. [77]	Minutiae and pore feature	Dempster shafer theory
2011	Qgechukwu [81]	Minutiae quadreuplet	Clustering technique
2012	Akhil and Anoop [76]	Geometric arrangement of neighbouring minutiae point	Hash-based indexing
2013	Lalhmingliana et.al. [82]	Ridge code	Clustering technique
2013	Alessandra [83]	Minutiae and singular point	Fusion method
2014	Uysal and Gorgunoglu [79]	Ridge pattern	X
2015	Guoqiang et.al. [72]	Minutiae information	Hash-based indexing

2.5 Chapter Summary

This chapter presented a different kind of algorithm related to fingerprint recognition system, such as fingerprint enhancement, fingerprint minutiae extraction and purification, fingerprint matching, fingerprint database and their indexing technique.