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"A Survey on Different Fingerprint Recognition Systems"

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Abstract- **In this paper we are comparing various fingerprint recognition system which are based on minutiae and ridge feature extraction. Here we are comparing various methods using minutiae features only or ridge features only or using both the methods together. This paper shows the direction for future scope on advancement of fingerprint recognition system. Methods focusing on conventional minutiae features (viz. minutiae type orientation and position) and methods focusing on additional ridge features (viz. ridge count(rc), ridge length(rl), ridge curvature direction(rcd) and ridge type(rt)) are observed and results supporting the respective methods are compared. Thus focus is emphasized on minutiae matching using ridge feature approach and future scope is discussed.All the methods used are generally minutiae based. Such systems cannot use more topological information such as ridge shape covering the entire FP image. Also the limitation of information still exists. Another drawback is that complex data structures and many parameters are used for FP matching. Thus a simple matching scheme was proposed by Heeseung et al. instead of developing complex distortion models or minutiae alignment model. Heeseung et al. incorporated conventional minutiae features and additional ridge features associated with corresponding minutiae sets. For evaluating any parameter a coordinate system proves helpful. Cartesian, cylindrical and spherical coordinate systems are used in various fields of science to measure various features. Similarly a ridge-based coordinate system is also defined to extract ridge features. Ridge count (rc), ridge length (rl), ridge curvature direction(rcd) and ridge type(rt) are the 4 elements of ridge features defined earlier. Here FPR system results will be proposed by addition of another ridge feature as ridge distance(rd).**

Index terms- **Co-ordinate system, Feature-extraction, Ridge.**

I.INTRODUCTION

Signature, iris, face and gait recognition proves to be insufficient when compared to fingerprint recognition (FPR). FPR is widely used across the globe due to its reliability in user identification. Its wide usage involves electronic personal ID cards, criminal investigation, limited access zone, e-commerce etc. even FPR system proves to be simpler than DNA matching system. The world has witnessed huge change and advancement in FPR but still some challenges needs to be overcome. For example most touch based FPR systems suffer from nonlinear distortions. Fig.1 shows two fingerprints (FP) of the same person. The position of minutiae are different because of distortions. These distortions could be because of skin elasticity, non-uniform pressure applied by a person, various position of placing the finger in the scanner etc.

Various methods are used by researchers to deal with these distortions. First could be stated as modeling the distortion of fingerprints [1]. Ross et al. and Bazen et al. compensated for deformations by using thin plate spline (TPS) model. But the amount of computational power used was too much for such approach. Capelli et al. calculated the nonlinear deformations of FP by stating plastic distortion model of a FP. This method was a huge progress in FPR systems but was not too sufficient.

Second method to deal with distortion could be stated as using special hardware or video sequences for detecting the distortions. Ratha et al. used special hardware to directly measure forces and torques on the scanner. This increased the hardware requirement of the system. Dorai et al. observed the FP video sequences for estimating the distortion which had the same drawback as that of Ratha et al.

Fig.1: Examples of skin distortions

Third important method could be stated as allowing a small amount of distortion in minutiae matching stages. Luo et al incorporated changeable tolerance boxes in the minutiae matching process. Moving from the centre towards the border of FP area, the size of the tolerance boxes are incrementally increased. While during minutiae matching distance normalization and local alignment was applied by Lee et al. Both methods suffer from the same drawback of increasing the probability of false FP matching as the size of the tolerance boxes are increased.

Fourth method to deal with distortions could be by measuring the local similarity. Jiang et al. efficiently showed a method which used the similarity measure defined between local structural features to align FP images. Kovacs–Vajna proposed a method which checked the correspondence of gray-scale profiles between every pair of minutiae from the template and the corresponding positions in the input images by using triangular matching. Thus to tolerate small location errors of features, the dynamic time warping method was used.

Also for all these approaches, a consolidation step may be implemented to check whether local similarity holds the same reputation at the global level.

Thus it could be clearly observed that all the methods used are generally minutiae based. Such systems cannot use more topological information such as ridge shape covering the entire FP image. Also the limitation of information still exists. Another drawback is that complex data structures and many parameters are used for FP matching. Thus a simple matching scheme was proposed by Heeseung et al. instead of developing complex distortion models or minutiae alignment model. Heeseung et al. incorporated conventional minutiae features and additional ridge features associated with corresponding minutiae sets. For evaluating any parameter a coordinate system proves helpful. Cartesian, cylindrical and spherical coordinate systems are used in various fields of science to measure various features. Similarly a ridge-based coordinate system is also defined to extract ridge features. Ridge count (rc), ridge length (rl), ridge curvature direction(rcd) and ridge type(rt) are the 4 elements of ridge features defined earlier. Here FPR system results will be proposed by addition of another ridge feature as ridge distance(rd). Ridge distance(rd) is here defined as the distance between two successive ridges.

Ridge distance(rd) will thus be invariant to any geometric translations *i.e.* rotational or translational, like other ridge features. Ridge features require 6 bytes for each minutiae pair where distribution of bytes is rc-1 byte, rl-1 byte, rcd-1 byte, rt-1 byte and rd-1 byte. Thus since maintenance of ridge structures is robust to direction, the 5 ridge features will precisely and concisely represent relationships between minutiae. Also this improves the overall FPR system performance when these features are combined since the correlation between proposed ridge features and conventional ridge features is low [2].

II. FINGERPRINT PREPROCESSING AND RIDGEFEATURE EXTRACTION

A. FINGERPRINT PREPROCESSING

Before extracting the proposed ridge features, we need to perform estimation of fingerprint image (see Fig. 2). These steps include typical feature extraction procedures as well as additional procedures for quality estimation and circular variance estimation. We first divide the image into 8x8 pixel blocks. Then, themeanand variance values of each block are calculated to segment the fingerprint regions in the image.

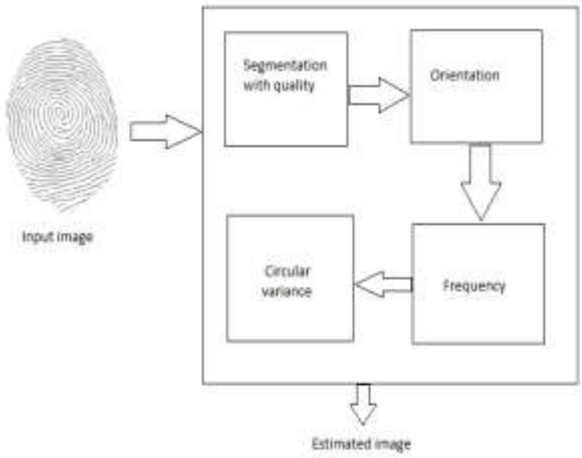

Fig.2.Various estimation of fingerprint image

We then apply the method described in to estimate the ridge orientation and the ridge frequency is calculated using the method presented in. The Gabor filter is applied to enhance the image and obtain a skeletonized ridge image. Then, the minutiae (end points and bifurcations) are detected in the skeletonized image.

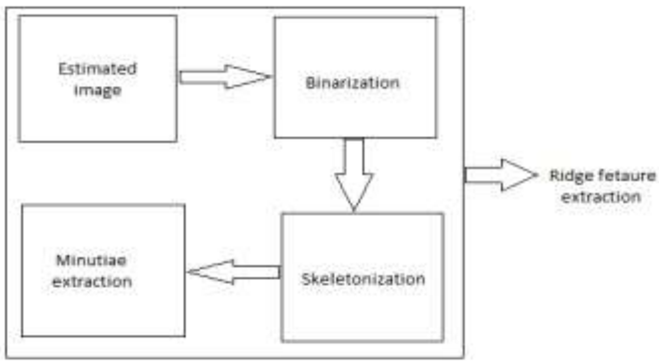

Fig.3 Ridge feature extraction

The quality estimation procedure is performed in order to avoid extracting false minutiae from poor quality regions and to enhance the confidence level of the extracted minutiae set. Furthermore, in regions where ridge flows change rapidly, such as the area around a singular point, it is hard to estimate the ridge orientations accurately or to extract the thinned ridge patterns consistently. Therefore, to detect regions which have large curvature, we apply circular variance estimation [3], [4]. The circular varianceof the ridge flows in a given block is calculated as follows:

$$\mathrm{Var}(\theta) = 1 - \frac{1}{n}\left[\left(\sum_{i=1}^{n}\cos\theta_i\right)^2 + \left(\sum_{i=1}^{n}\sin\theta_i\right)^2\right]$$

….. (1)

Where θ_i and n represent the estimated orientation of the $i$thblock and the number of neighboring blocks around the $i$thblock, respectively. In our experiments, we use eight neighboringblocks. Quality estimation and circular variance valuesare used to avoid generating feature vectors in poor quality regionsor in regions around singular points. Moreover, we adoptsome postprocessing steps to remove falsely extractedridges, such as short ridges and bridges. We can then extractthe ridge structures consistently against various noise sources.

B. RIDGE FEATURE EXTRACTION

1) PROPOSED RIDGE-BASED COORDINATE SYSTEM:

After performingthe pre-processing steps, we obtain the skeletonizedridges and minutiae information from the fingerprint image.We can then define ridge coordinates and extract ridge featuresbetween two minutiae. As shown in Fig. 3, each ridge-basedcoordinate system is defined by a minutia (called origin) andvertical and horizontal axes starting from the origin minutia.First, the vertical axis is defined by drawing a line passingthrough the origin and orthogonal to the orientation of theorigin. The axis also traverses the ridge flows orthogonally.In addition, to define the sign of the vertical axis accordingto the origin, the cross product between the orientation of the origin and the vector pointing from the origin to the side of the vertical axis is calculated as follows:

$$V_s = \text{sign}\left(\vec{O} \times \overrightarrow{V_n}\right)$$

…… (2)

where V_s, $\vec{O}$, and $\overrightarrow{V_n}$ represent the sign of the vertical axis, theminutia orientation vector, and the unit vector of the verticalaxis, respectively. Thus, we determine the positive and the negativeside of the vertical axis by checking the sign value of V_s.

To represent the relative position of the minutiae (minutiae M,N and J in Fig. 3) according to the origin, horizontal axesshould be defined. The horizontal axes are defined as ridges intersectingthe vertical axis.

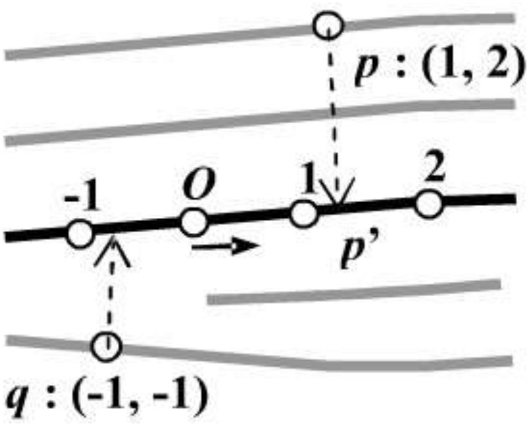

Fig.3. Ridge-based coordinate system

To define the sign of each horizontalaxis, the cross product between the vectors pointing from theintersection to the vertical and horizontal axes is calculated asfollows:

$$H_s = \text{sign}\left(\overrightarrow{H_n} \times \overrightarrow{V_n}\right)$$

…… (3)

where H_s, $\overrightarrow{H_n}$, and $\overrightarrow{V_n}$ represent the sign of the horizontal axis,the vector pointing from the intersection to the horizontal andthe vertical axis, respectively. In the ridge-based coordinatesystem, the ridge features that describe the relationship betweenthe origin (minutia O in Fig. 3) and an arbitrary minutia(minutiae M,N and J in Fig. 3), are described as follows:

$$\overrightarrow{V} = (\text{rc}, \text{rl}, \text{rcd}, \text{rt}, \text{rd})$$

…… (4)

whererc, rl, rcd,rt and rd represent the ridge count, ridge length, ridge curvature direction, ridge type and ridge distance respectively. Thesefour components form a ridge-based feature vector between twominutiae and this feature vector is used in the matching process.In the following sections, it is explained in detail about why these ridgefeatures were selected and the methods for extracting thesefeatures.

2) RIDGE FEATURE EXTRACTION:

In the general ridge countmethods [5], [6], the number of ridges that intersect thestraight line between two minutiae in the spatial domain iscounted. However, when the ridge-counting line is parallelto the ridge structures, the line may meet the same ridge atone point, at more than two points, or at no point, due to skindeformation (see Fig. 4).

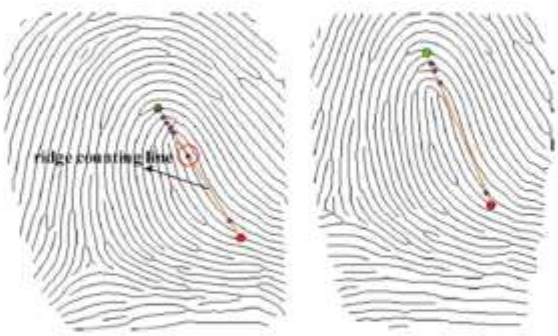

Fig.4. Example of ridge-counting errors using the general ridge counting methods.

Even though the two images are from the same fingerprints, the ridge count numbers between the two corresponding minutiae are different due to skin deformation.

Therefore, unlike existing ridge-counting methods, here, theridge count (rc) is calculated by counting the number of ridgesalong the vertical axis until the axis meets the ridge attachedto the neighboring minutia. The vertical axis is perpendicularto the ridge structures. Thus, the counted numbers are less affectedby skin deformation than in the results of the generalridge counting methods. In order to prove the effectiveness ofthe proposed ridge counting method, 50 fingers fromFVC 2002 DB1-Awere used and manually paired the correspondingminutiae among the five images from each finger. After pairing two corresponding minutiae, estimation of the probability distributionsof the absolute difference of the ridge counting numbersin each method is done[7], [8].

We can also say that this ridge count feature is more robust to skindeformation. Also if ridge distance(rd) is also included it would surely prove efficient for such systems. Furthermore, to increase the discriminating powerof the ridge count (rc) feature, we also consider the direction ofthe ridge count line. The ridge count (rc) is not always a positivenumber and the sign of the ridge count follows the sign ofthe vertical axis. If two minutiae are directly connected by thesame ridge, the ridge count would be zero.The ridge length (rl) is the distance on the horizontal axisfrom the intersection of the vertical and horizontal axis to aminutia. The ridge distance (rd) is the distance between two ridges on the vertical axis from the intersection of the vertical and horizontal axis to both minutiae. It is corresponding to two minutiae.

III. GENERALISED FINGERPRINT MATCHING ALGORITHM

The overall flow of the generalised fingerprint matching algorithm is as follows:

1) In the beginning, with the help of dynamic programming compare any pair of ridge-based coordinate systems extracted from reference image and the input image.
2) Abstract the maximally matched ridge-based coordinate pairs.
3) A breadth-first search (BFS) is performed to detect the matched pairs gradually.
4) For checking the validity of the matched coordinate pairs use the relative position and orientation of the minutiae and count its number.
5) Repeat steps 3 and 4 and then return the maximum number of matched minutiae.
6) Calculate the matching score.

After applying the above algorithm, i.e. dynamic programming is applied to find the optimal solution in matching two string sequences in the enrolled and input ridge-based coordinates. The ridge feature vectors in a ridge-based coordinate system are arranged in the order of their ridge count feature component (rc), then the order is invariant intrinsically. Therefore, the feature vectors in a ridge-based coordinate system can be stored as the elements of an ordered sequence. Thus, all the enrolled and input ridge-based coordinates are compared one by one and a similarity score is computed for the dynamic programming [9], [10].

IV.INDIVIDUAL RESULT OF MINUTIAE BASED RIDGE ORIENTATION APPROACH

Since the performance of a minutiae extraction algorithm relies heavily on the quality of the input fingerprint images, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module to ensure that the performance of the system is robust with respect to the quality of input fingerprint images. In practice, due to variations in impression conditions, ridge configuration, skin conditions (aberrant formations of epidermal ridges of fingerprints, postnatal marks, and occupational marks), acquisition devices, and non-cooperative attitude of subjects, etc., a significant percentage of acquired fingerprint images are of poor quality. The ridge structures in poor-quality fingerprint images are not always well-defined and, hence, they cannot be correctly detected. This leads to following problems:

1. A significant number of spurious minutiae may be created,
2. A large per cent of genuine minutiae may be ignored, and
3. Large errors in their localization (position and orientation) may be introduced.

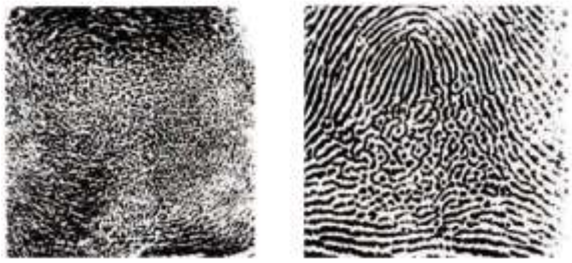

Fig.5 Fingerprint images of very poor quality

A fingerprint image is treated as a textured image, where an orientation flow field of the ridges is computed. To accurately locate ridges, a ridge orientation based computation method is used. After ridge segmentation, smoothing is done using morphological operators. Choi et al. introduced a novel fingerprint matching algorithm using both ridge features and the conventional minutiae features to increase the recognition performance against nonlinear deformation in fingerprints [11].

The proposed ridge features are composed of four elements: ridge count, ridge length, ridge curvature direction, and ridge type. These ridge features have some advantages in that they can represent the topology information in entire ridge patterns that exist between two minutiae and are not changed by non-linear deformation of the finger. For extracting ridge features, they have also defined the ridge based coordinate system in a skeletonized image.

With the proposed ridge features and conventional minutiae features (minutiae type, orientation, and position), they have proposed a novel matching scheme using a breadth first search to detect the matched minutiae pairs incrementally (Fig.6).

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Fig.6 Matched minutiae using the ridge feature vectors (solid circles represent matched minutiae and dotted lines represent the vertical axis of each minutia)

V. CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

In this paper we have compared various methods using minutiae based and ridge based approach separately. We also studied an algorithm using both ridge features and the minutiae. The ridge features consist of four elements (ridge count, ridge length, ridge curvature direction, and ridge type) and an additional element ridge distance is suggested and defined for better performance of methods using ridge based approach.Minutiae features (minutiae type, orientation, and position) are added to the above step to study an algorithm using a BFS to detect the matched minutiae pairs. Through variousexperimental results it is studied that the proposed method gives lower false acceptance rate compared to the conventional minutiae-based one. Hence we can conclude that with little increment of template size the proposed ridge features including ridge-distance wouldgive an additional help for FP matching [12].

We have presented a study covering different automatic fingerprint recognition techniques, presented by the experts in this field. Although many academic and commercial systems for fingerprint recognition exist, there is a necessity for further research in this topic in order to improve the reliability and performances of the current systems. Many unresolved problems still need to be explored and investigated. Thus future work for fingerprint matching lies in introducing new ridge features and better processing on low quality images.

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