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Distorted Fingerprint Matching Performance Improvement

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Abstract: **Fingerprint recognition is one of the most adopted techniques for user identification. Many highly accurate systems are commercially available. Poor quality of fingerprint image degrades the performance of existing biometric systems. Recent research has begun to tackle the problems of poor quality of fingerprints. So, we proposed a methodology to improve the matching performance of distorted fingerprints based on a single image. The orientation field of a fingerprint is important for feature extraction and matching. However, the reconstruction of orientation map of distorted fingerprints is a challenging problem. Conventional methods don't use prior knowledge of fingerprint. Hence, we proposed to use a enhanced feedback based approach using fuzzy logic for the reconstruction of orientation map. Further, the proposed enhanced fuzzy feature matcher(*EFFM)* takes a restructured ridge orientation map and minutiae map for matching. The proposed methodology enhances the performance and improves the fingerprint matching accuracy**.

Keywords: **Orientation Field Estimation, Enhanced Feedback, Minutiae, Fuzzy Feature Match (FFM).**

I. INTRODUCTION

Biometrics is the science of uniquely recognizing humans based on one or more intrinsic physical or behavioural traits. Due to its universality, uniqueness and low cost compared with other biometrics, fingerprint has emerged as one of the most reliable means of biometric authentication. Fingerprint authentication is commonly employed in forensic science to aid criminal investigations, e-commerce, and electronic personal ID cards, etc.

But the noises and distortions in fingerprint images added due to poor skin conditions, sensor noise and dry, wet or dirty fingers degrades the overall performance of existing systems. To deal with the distortions in fingerprint images and improve the matching performance, various methods have been proposed by many researchers. One approach to tackle the distortion is to improve fingerprint image acquisition or registration system. Existing systems requires scanners with video capturing capacity which needs more memory.

There are two types of distortions: photometric and geometric. Photometric distortions occur due to sensor noise and complex image background. Geometric distortions occur due to skin distortion such as elasticity of the skin, contact pressure, finger displacement, skin moisture content, imaging methods. When fingers immersed in water for a long period, gets wrinkled or shrivelled. A wrinkled fingerprint and mehandi on palm degrades the performance of biometric system. A wrinkled fingerprint adds non-isometric distortions in the fingerprint image. Finger with mehandi affects the scanning because finger contains dark colour. So, the acquired fingerprint has poor quality and feature extraction becomes difficult. When mehandi is drawn on palm, it adds a layer on the surface of skin. So, existing fingerprint scanners are not able to scan such a finger. There may be expanded layer of a mehandi at some location. As a consequence, the distance between fingerprint features such as minutiae and core points may change. Hence, a multispectral fingerprint scanner is used for such fingerprints, which is able to acquire subsurface features as well as surface feature even in poor conditions [2]. So, to handle geometric distortion has become a well research problem. One of the challenging problems is how to extract essential features from geometrically distorted fingerprint images.

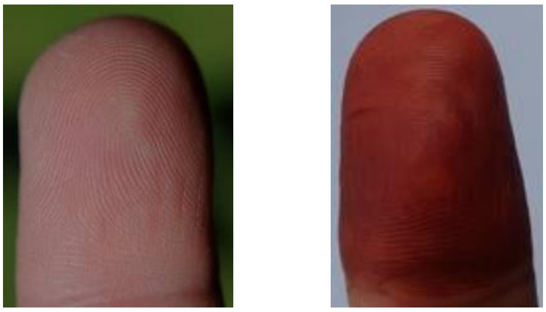

Fig. 1 a) A wrinkled fingerprint b) Fingerprint with mehandi

A fingerprint is a unique pattern of ridges and valleys on the surface of a finger of an individual. Orientation map and minutiae are the most critical features in fingerprint matching. Distortions in the quality of the acquired image results in spurious minutiae points or removal of real ones, thus directly affects the ability of algorithms to reliably match the fingerprints. Hence, it has become a challenging problem to develop a new approach to improve the fingerprint matching performance. In [1], authors focused on to detect elastic distortions. The ridge orientation map and period map of a registered fingerprint is the feature vectors used as an input. SVM classifier is trained to determine whether the input fingerprint is altered or not. A nearest neighbour approach is used to rectify the distortion in the input fingerprint. But it does not support rolled fingerprint. In [2], authors focused on the analysis and detection of altered fingerprints. They developed an algorithm to automatically detect altered fingerprints based on the fingerprint orientation field and minutiae distribution. They classified the alterations into three major categories: obliteration, distortion, and imitation.

Researchers have developed various algorithms to restructure an orientation map. In the proposed system, we use single image of fingerprint. Feature extraction means the orientation field estimation and minutiae extraction is a crucial step in fingerprint matching. Because orientation field and minutiae are the feature vectors used in fingerprint matching.

In distorted fingerprints, fingerprint matching is an interesting area for research. Because distorted fingerprints contain incomplete information or noise in it, which degrades the fingerprint matching performance as well as accuracy. Fingerprint matching can be categorized into four categories: a) Minutiae based, b) Pattern matching, c) Correlation based [1]. Fuzzy set theory handles uncertainty efficiently. So, to extract spurious or false minutiae from fingerprint image, fuzzy logic is used. The enhanced fuzzy feature matching (EFFM), a triangular feature vector is used to estimate the resemblance score between query and template fingerprint. But first, we find out matched triangles then find out attached matched triangles. Area of overlapping region is used to measure the similarity between two fingerprints.

The rest of the paper is organized as follows: Section 2 presents literature survey of previous approaches to restructure an orientation map and fingerprint matching. Section 3 presents the proposed method based on ridge orientation and frequency information. Section 4 presents conclusions and future work.

II. LITERATURE SURVEY

The distortion detection and removal is a well research problem. Due to distortion in the fingerprint image, required features may be lost. So, it has become crucial to handle distortions in the image or improve the quality of a fingerprint image. Extracting features out of poor quality fingerprints is the most challenging problem faced in this area.

Researchers have developed various approaches to reconstruct orientation field. In [3], authors introduced the concept of short time Fourier transform (STFT) Analysis for reconstruction of orientation field. This approach is noise sensitive so needs orientation smoothening of a fingerprint image before the enhancement. In [4], authors have proposed to fingerprint orientation field estimation algorithm for latent fingerprints. Dictionary of reference orientation patches is constructed using a set of true orientation fields. Because conventional algorithms do not use a prior knowledge of orientation patches of fingerprints. The use of a single global dictionary for the whole fingerprint has a drawback that a valid local ridge patterns may appear at an impossible location of fingerprint. This problem is analogous to real word error in spelling correction.

In [5], authors have developed a localized dictionaries-based orientation field estimation algorithm. In this algorithm, first latent fingerprint is registered and then noisy orientation patch is corrected by replacing it by real orientation patch in the local dictionary at the same location. But here it is very important to predict the location of a noisy orientation patch. In order to predict this location, author has used a Hough transform-based fingerprint pose estimation algorithm. Estimating fingerprint location from poor quality latent fingerprints is a very challenging problem and also a very under-researched topic. But in above both approaches, while constructing a dictionary, if noise is added in input fingerprints, false orientation patches are added in a dictionary [5].

In [6], authors designed an approach in which two dictionaries: orientation patch dictionary to restructure orientation patch and continuous phase patch dictionary to restructure the ridge pattern are constructed. Only the local orientation pattern is used for orientation field reconstruction. The use of global orientation prior knowledge and singular points can enhance the ridge orientation reconstruction. A fixed ridge frequency is used. This algorithm cannot reconstruct the field of ridge frequency directly by using the minutiae position and direction. In [7], authors proposed latent orientation field estimation via convolutional neural network utilizes prior knowledge of fingerprints and enhances the performance. To train the convolutional neural network, good quality images are required. So, if noise is added in training images, it affects the matching performance.

Various methods have been invented to deal with the distortions in fingerprint images and upgrade the matching performance. To handle nonlinear distortions, in [8], authors have implemented a normalized fuzzy similarity measure (NFSM) based method. To improve the invariance of global alignment, they used the local topological structure matching and to estimate the resemblance between the template and input fingerprints, NFSM is implemented. Still, there are few false fingerprint acceptances.

In [9], authors proposed a novel ridge feature extraction algorithm to enhance the exactness of fingerprint matching and to decrease the time complexity of ridge feature extraction process. In [10], authors have proposed a novel algorithm for fingerprint matching which is based on both ridge features such as ridge count, ridge length, ridge curvature direction, and ridge type and the minutiae features like minutiae type, orientation, and position and then performs breadth first search (BFS) to detect the similar pair of minutiae. But this algorithm could not work well for fingerprint images with small foreground are and poor quality images and does not use global knowledge of fingerprints. In [11], authors have designed a minutiae-based algorithm for fingerprint pattern recognition and matching. The distance between the minutiae and core points is an input feature to evaluate the matching scores for fingerprint images**.**

III. ENHANCED FUZZY FEATURE MATCH *(EFFM)*

Matching wrinkled fingerprints and fingerprints with mehandi to the registered fingerprints is a challenging problem as poor quality of image and less information. Hence, it is necessary develop a new approach to overcome this problem. Fuzzy logic is used to handle uncertainties and imperfection in an image. So, in the proposed system, we are using fuzzy logic to improve the matching performance and accuracy.

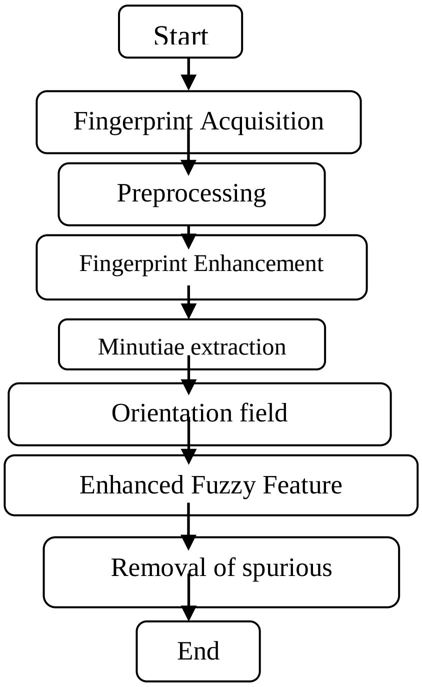

Fig. 2 The Flowchart of Proposed system

A. Fingerprint Preprocessing:

Fingerprint image is acquired from the user with the help of a multispectral scanner. This raw image is then converted to gray scale image. A distorted fingerprint or fingerprint with mehandi has a poor quality and contains less amount information, which ultimately affects the fingerprint matching performance. So, to upgrade the quality of a fingerprint image, image enhancement is done. Histogram equalization is a technique to adjust image intensities to enhance contrast. Local histogram equalization gives better result. By distributing the most frequent intensities values, areas of low contrast are converted to a higher contrast without affecting a global contrast. Then, the enhanced fingerprint image is binarized. Image thinning eliminates redundant pixels of ridges.

B. Minutiae Extraction:

Minutiae are the points at ridge endings and ridge bifurcation. To extract minutiae, crossing number *(CN)* concept is used which is most commonly used. The local neighbourhood of each ridge pixel in the image of a 3X3 window are scanned to extract minutiae.

P1	P2	P3
P4	P5	P6
P7	P8	P9

Fig. 3 3X3 neighbourhood

The *CN* value is computed as follows:

$$CN = 0.5 \sum_{i=1}^{8} |P_i - P_{i-1}| \qquad (1)$$

Table 1. Properties of crossing number

CN	Property
0	Isolated Point
1	Ridge ending point
2	Continuing ridge point
3	Bifurcation point
4	Crossing point

This method is simple and computationally efficient. Now, it becomes necessary to remove spurious minutiae. Euclidian distance (D) between two points is calculated. To eliminate spurious minutiae, following fuzzy logic is used.

a) Distance between bifurcation point and termination < D, remove that minutiae.

b) Distance between two bifurcation points < D, remove bifurcation.

c) Distance between two terminations < D, remove termination [12].

C. Orientation Field Estimation:

Orientation field represents the flow of ridges structure. As fingerprint image is distorted, it has poor quality. So, to find out accurate orientation field, we need to reconstruct it. To reconstruct the orientation field, we use the enhanced feedback mechanism is used. In this method, prior knowledge of orientation field and minutiae is used to extract the features. Hence, it improves the accuracy. The enhanced feedback is generated by calculating the orientation differences of distorted fingerprints and rolled or plain fingerprint. The enhanced feedback is used to rebuild the orientation field.

D. Gabor Filtering:

Gabor filtering possesses frequency selective and orientation selective properties. Gabor filtering is applied to enhance the ridge pattern. Gabor filter removes the noise from the fingerprint image without affecting the ridge structure.

E. Fingerprint matching using Enhanced Fuzzy Feature Match (EFFM):

Distorted fingerprint is matched with registered fingerprint using fuzzy logic. Fuzzy techniques can manage the vagueness and ambiguity efficiently.

a. Fuzzy Feature Match (FFM):

In fuzzy feature match (FFM), the triangle level similarity of query and template fingerprints is used to compute the similarity. The feature vector of each triangle is constructed which consists of distance between minutiae, the angle between the direction from minutiae, the orientation differences within the region of minutiae and the angle between the orientation of minutiae with the direction of the interior angle bisector. The feature vector of each triangle is represented as:

$$FT_K = \{d_{ij}, d_{jk}, d_{ik}, \Psi_i, \Psi_j, \Psi_k, OZ_i, OZ_j, OZ_k, \alpha_i, \alpha_j, \alpha_k\} \quad (2)$$

where,

$d_{ij} =$ the distance between minutiae i and j,

$\Psi_i =$ the angle between the direction from minutiae i to j and the direction from minutiae i to j,

$OZ_i =$ the orientation differences within the region of minutiae i,

α_i = the angle between the orientation of minutiae with the direction of the interior angle bisector of corner.

This feature vector is used to compute the similarity between input and template fingerprint. Let FT_I be a feature set of input fingerprint.

$$FT_I = \{d_{ij}, d_{jk}, d_{ik}, \Psi_i, \Psi_j, \Psi_k, OZ_i, OZ_j, OZ_k, \alpha_i, \alpha_j, \alpha_k\} \quad (3)$$

Let FT_T be a feature set of input fingerprint.

$$FT_T = \{d_{ij}',d_{jk}',d_{ik}',\Psi_i',\Psi_j',\Psi_k',OZ_i',OZ_j',OZ_k',\alpha_i',\alpha_j' \alpha_k'\} \quad (4)$$

These two feature set of local triangle of input and template fingerprints are used to calculate the similarity between fingerprints. Measure the similarity between fingerprints as follows:

$$\overrightarrow{D_{diff}} = \{|d_{IJ} - d_{IJ}'|,| d_{jk} - d_{jk}'|,| d_{ik} - d_{ik}'|\} \quad (5)$$

$$\overrightarrow{\Psi_{diff}} = \{|\Psi_i - \Psi_i'|, |\Psi_j - \Psi_j'|, |\Psi_k - \Psi_k'|\} \quad (6)$$

$$\overrightarrow{OZ_{diff}} = \{|OZ_i - OZ_i'|, |OZ_j - OZ_j'|, |OZ_k - OZ_k'|\} \quad (7)$$

$$\overrightarrow{\alpha_{diff}} = \{|\alpha_i - \alpha_i'|, |\alpha_j - \alpha_j'|, |\alpha_k - \alpha_k'|\} \quad (8)$$

These are genuine distorted pattern parameters. In this way, we find out the similarity vector. The FFM method maps a similarity vector pair to a normalized quantity within the real interval [0,1], which quantifies the overall image to image similarity.

Calculate weights of each similarity vector. To calculate a weight, centre-favoured scheme is used. The higher weight is assigned to a triangle which is closer to a centre. To check the similarity between fingerprints, FFM calculates the summation of all weighted entries of all similarity vectors. FFM similarity measure can be expressed as follows:

$$Sim = [(1 - p) wA + pwB] L(T,I) \quad (9)$$

where,

wA = the normalized area percentage of both template and input fingerprints,

wB = the normalized weight which favour triangle near the image centre,

p = the probability that the similarity between the template and input fingerprints is greater than threshold and p € [0,1] adjusts the significance of wA and wB,

L(T, I) = the weighted entries of similarity vector of the overall image [13].

b. Enhanced Fuzzy Feature Match (EFFM):

In the enhanced fuzzy feature match *(EFFM)* methodology, along with the distance between minutiae, the direction angle between two minutiae, the orientation angle and the angle between the orientation of minutiae with the direction of the interior angle bisector, we consider the type of minutiae.

Here, feature vector of each triangle is expressed as:

$$FT_K = \{d_{ij}, d_{jk}, d_{ik}, \Psi_i, \Psi_j, \Psi_k, OZ_i, OZ_j, OZ_k, \alpha_i, \alpha_j, \alpha_k, T_i, T_j, T_k\} \quad (5)$$

T_i, T_j, T_k are the minutiae types of coordinates of triangle. Above feature vector is used to map the similarity between the input and template fingerprint. Steps involved in the enhanced fuzzy feature match *(EFFM)* are as follows:

Step I: Find out triangles of input and template fingerprint having same minutiae type.

Step II: Then, we check the similarity between triangles using the method expressed in FFM.

Step III: If triangles are matched, then find out matched triangles which are attached to the previously matched triangle.

Step IV: If no two triangles are matched, consider new feature vector and repeat step II and III.

Step V: If the area of matched triangles is greater than threshold value, fingerprints are matched.

IV. CONCLUSION

Existing fingerprint scanners are unable to scan fingerprints having mehandi drawn on finger. So, we proposed to use multispectral fingerprint scanners. There are two types of distortions: photometric and geometric distortions. In this paper we focused on geometric distortions which occur due to skin distortions, fingerprint displacement, wrinkled fingerprint, etc. Due to poor quality of images, minutiae are extracted using crossing number concept. To remove spurious minutiae, fuzzy logic is applied as fuzzy logic handles uncertainties and more efficient. Orientation field is reconstructed using enhanced feedback which uses prior knowledge. So, it improves the accuracy of fingerprint matching. Enhanced fuzzy feature matcher *(EFFM)* is used for fingerprint matching which provides accuracy.

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