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Biometric Cryptosystem Based on Delaunay Quadrangle Structure for Fingerprint Template Protection and Person Identification

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Abstract: Biometric cryptosystems plays a significant role in cryptographic key generation and biometric template protection. An effective biometric cryptosystem protects biometric templates. In this paper, a Delaunay quadrangle based fingerprint recognition system is introduced. The main objective of this system is to protect the fingerprint template from unauthorized person and for person identification. Delaunay Quadrangle based system is introduced in order to overcome the drawback nonlinear distortion-induced local structural change faced by the Delaunay triangle-based structure. Delaunay quadrangle based Fixed-length and alignment-free feature vectors extraction are less sensitive to nonlinear distortion and it is more discriminative than those from Delaunay triangle structure and this technique can be used for biometric template protection. Furthermore, by using Delaunay quadrangle a unique topology code is constructed. This unique topology code not only helps to carry out accurate local registration under distortion condition, but it also highly enhances the security of biometric template data. Experimental result shows that Delaunay quadrangle-based system with topology code generation achieves better performance and higher level of security compare to Delaunay triangle based system and Delaunay quadrangle based system without topology code generation and other similar systems.

Key words: Fingerprint · Delaunay Triangle · Delaunay Quadrangle · Voronoi diagram · Topology code · Template protection

INTRODUCTION

Biometric Fingerprint based identification is one of the most reliable and highly accurate technique compare to other biometric techniques like palm print, Iris and Face. There are two techniques which can be used in fingerprint identification systems. They are minutiae-based technique and texture-based technique. In General, the minutiae-based methods are highly popular and more reliable [1]. In minutiae-based technique [2, 3], a fingerprint is represented by a set of minutiae, which are called as ridge ending and bifurcation. In recent years, although much attention has been given to minutiae-based matching technique, the biometric fingerprint matching is not an easy task due to the uncertainty caused by fingerprint rotation, translation and nonlinear deformation at each fingerprint image acquisition. To overcome the uncertainty in biometric fingerprint and to improve the recognition level, the Delaunay triangle based structure technique is proposed. By using this Delaunay [4] triangle based technique the relative position and orientation between the minutiae and its neighbors will remain unchanged under rotation and translation.

Existing Delaunay Based Technique

Delaunay Triangle Based Structure: The Delaunay triangle based structure has many excellent characteristics [5, 6]. First, this system has good structural stability under positional disruptions [7]. During translation, rotation a small scale change caused by nonlinear distortion condition each minutia is likely to maintain a similar structure with its neighboring minutiae point. Second, Delaunay triangulation net can even maintain structural stability under random positional perturbations

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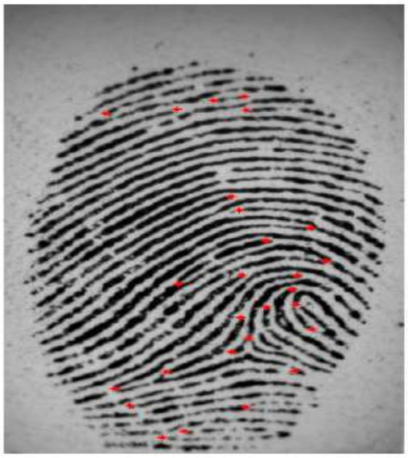

Fig. 1: Fingerprint minutiae points

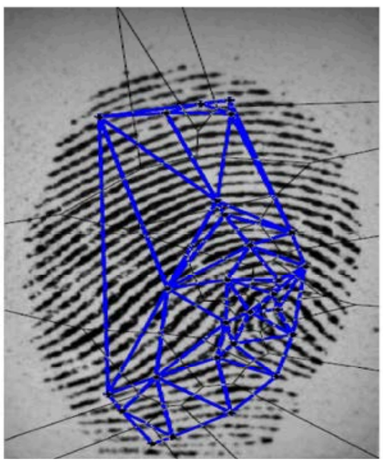

Fig. 2: Voronoi diagram (thin line), Delaunay triangulation net (bold line)

condition [8]. Fig 1. shows a set of minutia points and Fig 2. shows the Voronoi diagram (thin line) and Delaunay triangulation net (bold line) formed by this minutia point set.

Due to the excellent properties of the Delaunay triangulation net, a number of methods have been proposed for minutiae-based fingerprint matching. In [9], the author proposed an approach that helps to form a Delaunay triangulation net using the minutiae points. In [10], instead of best-matching minutiae some possible best-matching edge pairs are first found in local structure matching and then by the triangle matching procedure guided by the aligned-edges a global matching score between two fingerprint images is formed.

In both [11] and [12], first some similar minutiae pairs are selected from both template and query images as reference points for alignment. Then on the aligned feature sets fingerprint matching is performed. In [13], first, the identification of the Delaunay triangle-based features is carried out and to align a fingerprint images a function called Radial Basis Function (RBF) is used. Further, the matching score between the template and query image with additional information is calculated using global matching technique. In [14], by joining several triangles based on the credibility of each triangle sets which is formed by Delaunay triangulation, a larger local structure (growing regions) are generated. Then via several growing regions a much larger local structure (fusion region) is fused. This step is similar to the concept proposed in [15] which merges minutiae triangles based on compatibility in an extended searching step.

Fingerprint Template Protection: Usually in biometric fingerprint authentication systems, templates are stored in a database during enrollment stage and in the verification stage it will be compared with queries. From the storage of raw template data as biometric traits, serious security concerns may arise. Once they are compromised, they cannot be changed like passwords or tokens. Biometric cryptosystem and cancellable biometrics are the two techniques used to provide secure protection to biometric templates. In cancellable biometrics, by a non-invertible transformation function during the enrolment stage, the original template features are transformed into a new format. During the authentication stage, the same non-invertible transformation function is applied to query features and fingerprint matching is performed between the transformed template and query features. By above method, original template features are protected.

Limitations of Delaunay Triangle Structure: In Delaunay Triangle based structure, The local Delaunay structure which contains that minutia will be altered if distortion moves a minutia out of the tolerance region. To overcome the above limitation we go for Delaunay Quadrangle based structure for fingerprint identification.

Proposed Technique: The main objective of the proposed Delaunay quadrangle based technique is to overcome the drawback local structural change suffered by Delaunay triangle based structure under nonlinear distortion. This Delaunay quadrangle based structure provides more security for template data by using topology code and pinsketch for identification purpose. The proposed

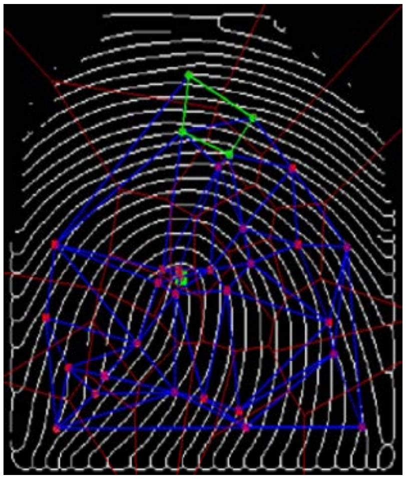

Fig. 3: Delaunay Quadrangle formation from voronoi diagram

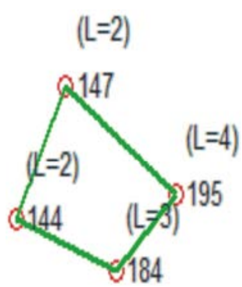

Fig. 4: Topology code construction

technique provides unique topology code of fixed length. This technique can be used to carry out accurate local registration under distortion condition.

Delaunay Quadrangle Construction: Delaunay quadrangle based technique is built upon the construction of Delaunay triangulation net. The algorithm for the construction of Delaunay triangulation is detailed in. A set of minutiae is given as $M = \{m_i\}_{i=1}^{N}$ Where, N is a set of minutiae. In order to construct Delaunay triangulation, first voronoi diagram must be formed. The voronoi diagram partitions entire region into small cells based on minutiae points in the image. After the construction of voronoi diagram. The Delaunay triangle can be formed by joining the centre points of every pair of neighboring in voronoi region. Next Delaunay quadrangle can be formed by combining any two Delaunay triangles as shown in Fig 3.

Topology Code Formation: The topology code construction acts as a binding key for fingerprint template protection. Let us assume that the quadrangle formed is Q (A B C D). The steps for the construction of topology code is given as follows. First, The angle value for the points A,B,C and D are calculated. Then, the topology code 2 2 3 4 is assigned to the points Q (A B C D) based on the increasing angle values respectively.

From Fig 4. it is found that the minimum angle value is 144° so that point is assigned with the first topology value '2' then the next smallest angle is 147° so that point is assigned with the next topology value '2'. Similarly the third smallest angle is 184° it is assigned with the value '3' and finally, the point with 195° is assigned with the code '4'. The final code is obtained by considering the top

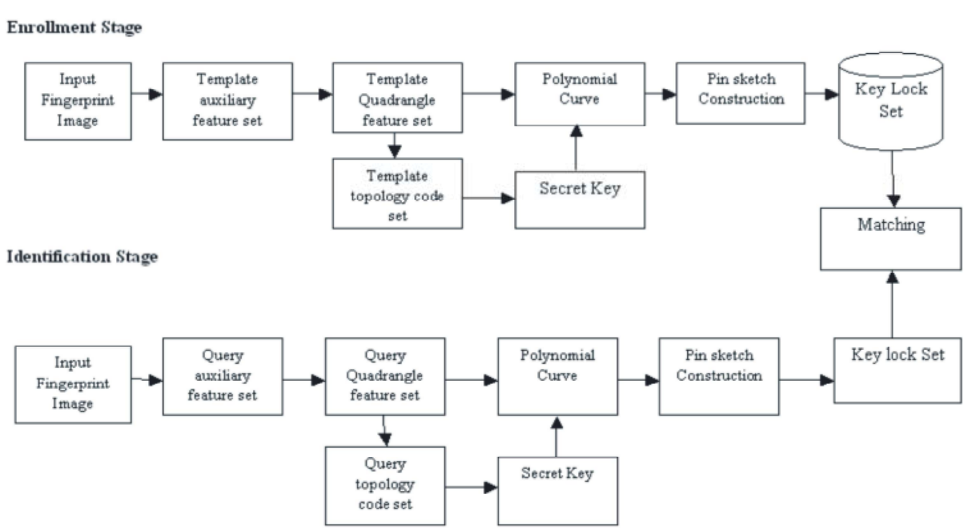

Fig. 5: Block Diagram of Proposed Technique

most row value as first point and the rest of the values are taken in clockwise direction. So, the final topology code for the above case is "2 4 3 2". The topology code is then combined with the fingerprint features using pinsketch technique and then a polynomial curve is constructed. Finally the fingerprint minutiae features along with the topology code are stored in the database in the enrollment stage as shown in the Fig 5.

Fig 5. shows the block diagram of the proposed technique. The proposed scheme is classified into two stages namely Enrollment stage and Identification stage. In the Enrollment stage multiple fingerprints are collected and some preprocessing steps like Binarization, Thinning, Minutiae extraction are carried out. With the extracted minutiae points Delaunay Quadrangle structure is formed with the help of voronoi diagram. Then a template quadrangle feature set is constructed for the selected four minutiae points during quadrangle formation. Then a Topology code will be generated for that four points and it will be binded with the template feature set and polynomial curve has been plotted. By using polynomial curve equation a key lock set is generated and stored in the database.

In the Identification stage, the fingerprint of an individual is fetched and the preprocessing steps, Delaunay Quadrangle generation process are carried out similar to the steps in enrollment stage. Then a polynomial curve is generated with the help of the topology code. Finally a key lock set is constructed and that will be compared with the key lock set in the enrollment stage for matching.

RESULTS AND DISCUSSION

The proposed scheme is implemented using the MATLAB Software. Here we are going to consider fingerprint template of different persons. In our system we are going to divide the experiment into two stages namely enrollment stage and verification stage. In the Enrollment stage, we are going to fetch the multiple fingerprint images of an individual and perform some pre-processing tasks and then we are going to extract the minutiae of the Fingerprint templates. Next, Voronoi diagram is constructed. Then the Delaunay quadrangle process is carried out in order to generate the topology code. Furthermore, a polynomial curve is constructed for the topology code obtained in the above process. At last the generated polynomial curve for the topology code along with the fingerprint template is stored in the database.

In the Identification stage, a fingerprint of an individual is given as input and the process similar to that in the enrollment stage is carried out. The topology code is generated and the polynomial curve is constructed then keylock set is obtained. Finally a key lock set is constructed and that will be compared with the key lock set in the enrollment stage for matching.

Here the performance of the system is verified using two parameters namely FAR and FRR.

False Acceptance Rate (FAR): It is the probability of an imposter being accepted as an authorized user

False Rejection Rate (FRR): It is the probability of a legitimate user being rejected as an imposter.

- FAR is the ratio of the number of False Acceptances (FA) to the number of identification attempts.

$$FAR = \frac{\text{Number of FA}}{\text{Number of identification attempts}} \quad (1)$$

- FRR is the ratio of the number of False Rejections (FR) the number of identification attempts.

$$FRR = \frac{\text{Number of FR}}{\text{Number of identification attempts}} \quad (2)$$

Table 1. gives the performance analysis of the proposed scheme. Here the performance of the system is evaluated using the parameters FAR and FRR. In the TABLE I. the term N denotes the number of templates taken in the data base. First, the value of N is taken as N=5 and the FAR and FRR values are obtained as 0.053 and 0.05 respectively. Similarly by varying the value of N to N=7 the FAR and FRR will be 0.042 and 0.048 and for the value of N=7 the values of FAR and FRR are obtained as 0.035 and 0.041. Form the above values we can conclude that, as the number of templates in the database increases the corresponding values of FAR and FRR will get reduced in order to give efficient results.

Table 1: Performance Evaluation

Parameters	N=5	N=7	N=9
FAR	0.053	0.042	0.035
FRR	0.05	0.048	0.041

CONCLUSION

Although the Delaunay triangle-based structure has good local stability, the nonlinear distortion which generally exists in fingerprint images, may still change the local structure. This structural alteration might generate some Delaunay triangles that are different to those constructed from their corresponding minutiae in the template image. To overcome this problem, we propose to adopt the Delaunay quadrangle-based structure because Delaunay quadrangles are more stable and robust. They also contain more attributes than Delaunay triangles and hence benefit feature representation. The fixed-length, alignment-free feature vector extracted from each Delaunay quadrangle is less sensitive to nonlinear distortion and more discriminative than that from a Delaunay triangle and is also compatible with the existing template protection techniques, e.g., Pin Sketch. Furthermore, the unique topology code originated from each Delaunay quadrangle can assist in accomplishing good local registration in the presence of nonlinear distortion. Experimental results have shown that the use of topology code helps the proposed system to achieve better biometric fingerprint recognition. Another benefit of the topology code is that it can further enhance the security of the overall system on top of what is provided by the secure sketch. Thus the proposed system can be used for both fingerprint template protection and recognition purpose.

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