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An efficient minutiae based geometric hashing for fingerprint database ☆

Umarani Jayaraman *, Aman Kishore Gupta, Phalguni Gupta

Department of Computer Science and Engineering, Indian Institute of Technology Kanpur, Kanpur-208 016, India

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ABSTRACT

This paper proposes an efficient indexing technique for fingerprint database using minutiae based geometric hashing. This technique consists of two stages, known as *indexing* and *searching*. For an accurate match at the time of searching, it has proposed a fixed length feature vector built from each minutia, known as Minutia Binary Pattern. Unlike any existing geometric based indexing technique, the proposed technique inserts each minutia along with the feature vector exactly once into a hash table. As a result, it reduces both computational and memory costs. Since minutiae of all fingerprint images in the database are found to be well distributed into the hash table, no rehashing is required. Experiments over FVC 2004 datasets prove the superiority of the proposed indexing technique against well known geometric based indexing techniques.

1. Introduction

Fingerprint recognition system is used to identify a subject (human) from a large biometric database. One can do this task by searching a query image (henceforth termed as *query fingerprint*) against all images in the database (henceforth termed as *model fingerprints*) of subjects. Generally, the process to retrieve each model fingerprint from the database and to compare it against the query fingerprint for a match is computationally inefficient. A fingerprint image has the following characteristics:

- Number of minutiae extracted from a fingerprint of any subject at any two time instants may not be same.
- There may be too many minutiae in a fingerprint; some of them may be false. Also, there is a possibility of missing some true minutiae.
- There may be partial occlusion in a fingerprint of a subject and it may overlap with some other subjects that are not present in the database.
- A query fingerprint may be rotated and translated with respect to the corresponding model fingerprints in the database.

Existing fingerprint indexing techniques can be classified on the basis of the methods of extracting features such as singular points [1], directional field [2], local ridge-line orientations [3–7], orientation image [8,9], minutiae [10–12], minutiae descriptor [13], multiple features [14], matching scores [15,16], SIFT features [17] and line features [18]. But most of the matching algorithms are based on minutiae; so use of minutiae to index the fingerprint database is beneficial in many respects.

Minutiae based techniques derive robust geometric features from triangles formed by triplets of minutiae and use hashing techniques to perform the search. An indexing technique for fingerprints has been proposed in [19] where geometric features obtained from triangles formed by triplets of minutiae are used for indexing. Triangles are formed between all possible combinations of minutiae triplets. During *indexing* stage, nine indexing keys *viz* the length of three sides (L_i), the ridge count between each pair of vertices (R_i) and minutiae angles encoded in a transformation-invariant fashion (θ_i) where $i=1,2,3$ have been considered. The index generated by the FLASH (Fast Lookup Algorithm for String Homology) framework serves as the key to identify triangles that resemble one another. At *searching* stage, index $I=((L_i, R_i, \theta_i)$: $i=1,2,3)$ generated from all possible triangles of a query fingerprint is used to retrieve all triangles stored in the table that are labeled with the same index. Matching is performed between triangles based on the transformation parameter clustering. Parameters such as translation in X,Y direction, rotation θ, along with the fingerprint ID are used to perform the matching. To reduce the false correspondences, geometrical constraints from minutiae triangles *viz* maximum length of three sides, median and

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* Corresponding author. Tel.: +91 512 2597579; fax: +91 512 2597647.
E-mail address: umarani@cse.iitk.ac.in (U. Jayaraman).

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minimum angles, triangle handedness, type, direction and ridge count minutiae density are considered in [20]. Since triangles are formed using all possible minutiae, it increases both memory and computational cost.

In [21], a fast and robust projective matching technique has been proposed for fingerprints. The non-linear distortion and noise added in the fingerprint images at the time of image capturing are modeled as transformation in the projective domain. Matching of the fingerprints involves computation of the homography matrix for the projective transformation, mapping of the minutia points by this homography and finally computation of the points that match each other within a pre-determined threshold. It makes use of Geometric Hashing [22] for fast match. This technique consists of two phases viz. *preprocessing* and *recognition* phases. Assume, fingerprint of a subject contains a maximum of n minutiae and there are N fingerprints in the database. Let b be the bases *i.e.* the number of feature points used to obtain the hash table through geometric hashing. The value of b is determined by the class of invariants. For example, $b=2,3,4$ are, for a similarity transformation, an affine transformation and a perspective transformation respectively [23]. In *preprocessing* phase, all model fingerprints are represented in similarity invariant way. For each ordered pair ($b=2$) of minutiae of a model fingerprint, a coordinate system is defined and the coordinates of remaining $n-2$ minutiae of the model fingerprint are recomputed based on this coordinate system. The recomputed coordinates are used as the index of a hash table where entry of the form (bases, model) is recorded. Hence, there are totally $n \times {}^{n}C_2$ possible entries of bases pairs into a hash table. At the time of *recognition* phase, an arbitrary ordered bases (minutiae) is chosen from the query fingerprint. The coordinates of the remaining minutiae of the query fingerprint are recomputed in terms of the coordinate system defined by this bases. The recomputed coordinates of each minutia are used as the index into hash table and for each entry (bases, model) in the hash table, a vote is casted. If an entry (bases, model) scores large number of votes, then this bases corresponding to the one is selected from the query fingerprint. However, geometric hashing may not be suitable because it uses $n \times {}^{n}C_2$ bases pair where n is the maximum number of minutiae of a fingerprint.

In [24] geometric features obtained from Delaunay triangles of minutiae have been used for indexing the fingerprints. It can be shown that if n is the number of minutiae, Delaunay triangulation produces $O(n)$ triangles. However, the major issue with Delaunay triangulation is that it is more sensitive to noise and distortion. For example, if some minutiae are missed or added (spurious minutiae), the structure of Delaunay triangulation gets seriously affected. Hence, this technique requires high quality of fingerprint images. Fig. 1 shows an example of both fingerprints which are taken at two different time instants from the same person. Note that there is significant change in their Delaunay triangles. Some of the well known geometric based indexing techniques for fingerprint have been summarized in Table 1.

This paper presents an efficient indexing technique which uses invariant spatial (distance) and directional (angle) information to index each minutia into a hash table. It has proposed fixed length feature vector built from each minutia, known as Minutia Binary Pattern (MBP), for the accurate match at the time of searching. The technique is robust to translation and rotation. It can be conveniently represented by a hash table which contains spatial and directional information. Each minutia can be uniquely identified by its distance and angle information from its core point and is

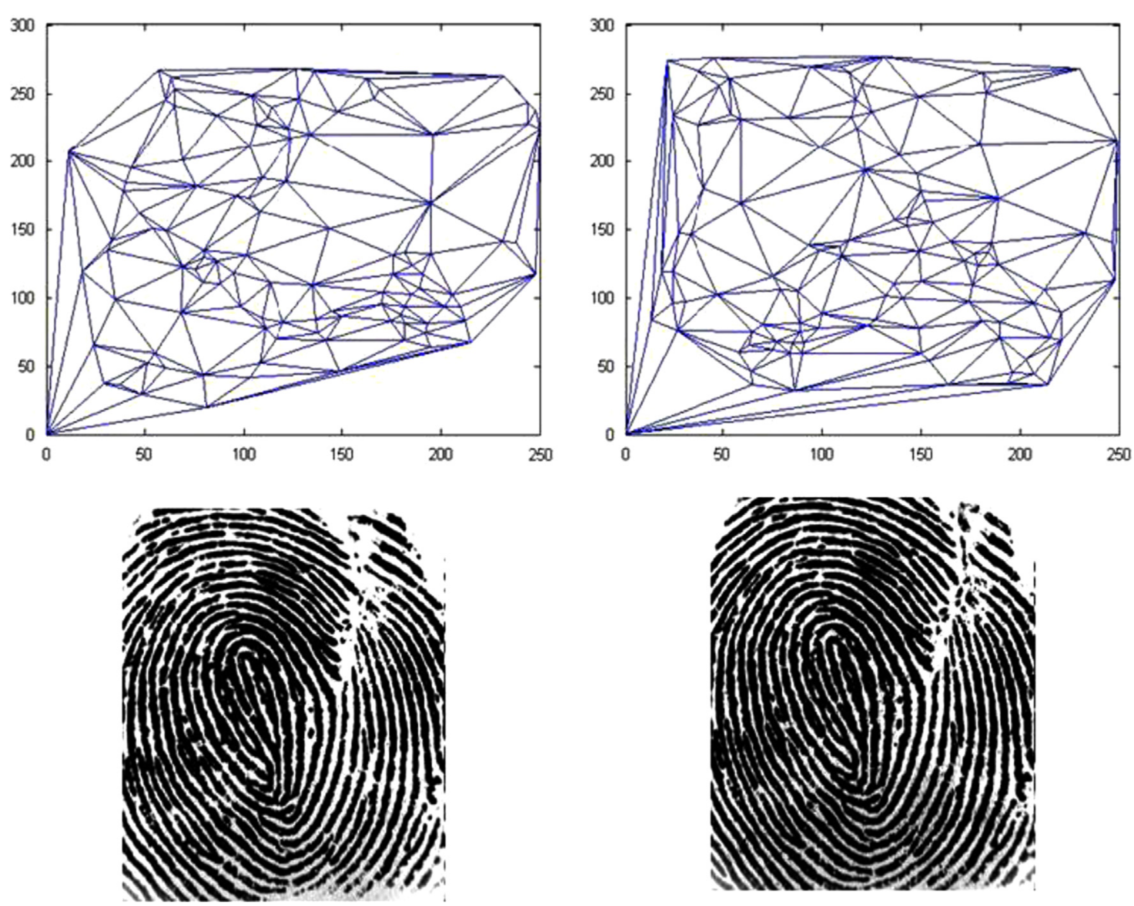

Fig. 1. Delaunay triangulation: Both fingerprints are taken at different time from same person.