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Fingerprint indexing with pose constraint

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ABSTRACT

Fingerprint indexing is critical for identifying fingerprints efficiently in large-scaled fingerprint databases. The state-of-the-art indexing accuracies are achieved by minutiae-based indexing approaches. A major difference of these approaches is how they deal with fingerprint registration problem. Some of the approaches do not use registration, while others perform relative/pairwise registration (e.g., based on mated minutiae between two fingerprints). However, the former approach is not accurate, since without geometric constraints, many false matches can be found even for non-mated fingerprints. The latter is not efficient for large databases since the relative registration step has to be performed for each pair of fingerprints. It is desirable to develop an absolute registration approach, which can register any single fingerprint into a common coordinate system, and therefore can address efficiency and accuracy problems simultaneously. In this paper, we proposed a fingerprint pose estimation algorithm which can register fingerprints into a common finger coordinate system. Fingerprint pose estimation problem is viewed as a two-class classification problem and approached by sliding window classifiers trained on labeled data. Ridge orientation information is used as features instead of singularities which are often affected by noise. With the pose estimation, we are able to refine the matched minutiae with global spatial constraint. By combining the proposed pose estimation algorithm with an improved Locality Sensitive Hashing algorithm for MCC descriptor, our indexing system outperformed previous state-of-the-art on widely used databases and its scalability was tested on a large database with one million fingerprints.

1. Introduction

Fingerprint is easy to be measured, and believed to be unique among individuals. These intrinsic characteristics and the great advance in fingerprint recognition technologies make it the most widely used biometrics. Nowadays, large scale fingerprint recognition systems can have more than millions of fingerprints. For the task of identifying a fingerprint in large databases, fingerprint indexing algorithm is usually first used to quickly select a subset of candidates and then accurate but slower matching algorithm is employed to determine the final result [1,2].

Fingerprint indexing approaches can be roughly classified into two categories: level-1 indexing approaches and level-2 indexing approaches. Level-1 approaches use level-1 features, namely, ridge orientation map and ridge frequency map [3–6]. Fingerprint classification can be viewed as a special case of level-1 indexing approach, where the dimensionality of the feature vector is one. Level-2 approaches are based on level-2 features, namely, minutiae. Level-1 indexing approaches are commonly faster than level-2 indexing approaches, as level-1 features can be represented as compact feature vectors. On the other side, since minutiae contain more discriminative information of fingerprints than ridge orientation and frequency maps, level-2 indexing approaches should be more accurate if implemented properly. Some indexing approaches combine both features to make full use of them and get better performance [7,8]. The proposed approach belongs to level-2 indexing approach.

Minutiae-based indexing approaches generally extract a set of invariant features based on minutiae. Examples of invariant features include descriptors of minutiae [9], features of minutia triplets [10–12], and features of minutia quadruplets [13,14]. Most of the level-2 indexing approaches are based on the inverted index [15], which is a popular data structure in information retrieval. The basic framework of these indexing algorithms is briefly described as follows. A fingerprint is represented as a set of invariant features based on minutiae. In the offline stage, inverted index is used to store all the invariant features of all gallery fingerprints. In the online stage, given a query fingerprint, for each of its invariant features, corresponding invariant features in the inverted index

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are found and a vote is cast for each corresponding gallery fingerprint. Finally, gallery fingerprints are ranked according to their received votes.

Although most level-2 indexing algorithms adopt the above basic framework, they may have some important differences. Two key differences are whether a global spatial transformation constraint is enforced or not and how the global constraint is enforced. The global constraint requires that the transformation between each matched minutiae pair should be close to a same rigid transformation. Without a global constraint, an invariant feature in the query fingerprint may have many false matches in non-mated gallery fingerprints. By enforcing global constraint correctly, the number of false matches in non-mated gallery fingerprints can be significantly reduced while the mated gallery fingerprint is less affected. See Fig. 1 for an example.

If two fingerprints are registered in the same coordinate system, global constraint can be simply enforced by requiring the matched minutiae to be close in both location and direction. Hence the key of enforcing global constraint is to register fingerprints. There are two different methods for fingerprint registration: absolute registration and pairwise registration. The most common method for absolute registration is to use singular points (loop/delta) for fingerprint registration. However, singular points are not present in some fingerprint images (fingerprints of plain arch type and incomplete fingerprints) and are often affected by noise which makes them not suitable for the use in absolute registration. That is why existing minutiae-based indexing approaches either enforce it by pairwise registration [10] or simply ignore it [9], since pairwise registration is not efficient for large databases.

To efficiently utilize global constraint in fingerprint indexing, we propose a pose estimation algorithm to register fingerprints into a unified coordinate system. We learn classifiers with manually marked samples to detect well positioned fingerprint in an image. We use ridge orientation as dominant features in the algorithm instead of singularities, which makes our algorithm less sensitive to noise. Pose determined by the well positioned fingerprint is shown in Fig. 1. We use the pose as global spatial constraint to refine the matched minutiae. As we can see from the figure, false correspondences are reduced with such constraint, especially for non-mated fingerprints. By combining the proposed pose estimation algorithm with an improved Locality Sensitive Hashing algorithm for MCC descriptor, our indexing system achieved state-of-the-art performance on several public domain databases as shown in experiments.

The rest of this paper is organized as follows: in Section 2, published algorithms for fingerprint indexing and fingerprint pose estimation are reviewed. Our pose estimation algorithm is introduced in Section 3. Details of how we retrieval fingerprints with estimated pose is explained in Section 4. The improved Locality Sensitive Hashing algorithm is also presented in this section. Then,

a

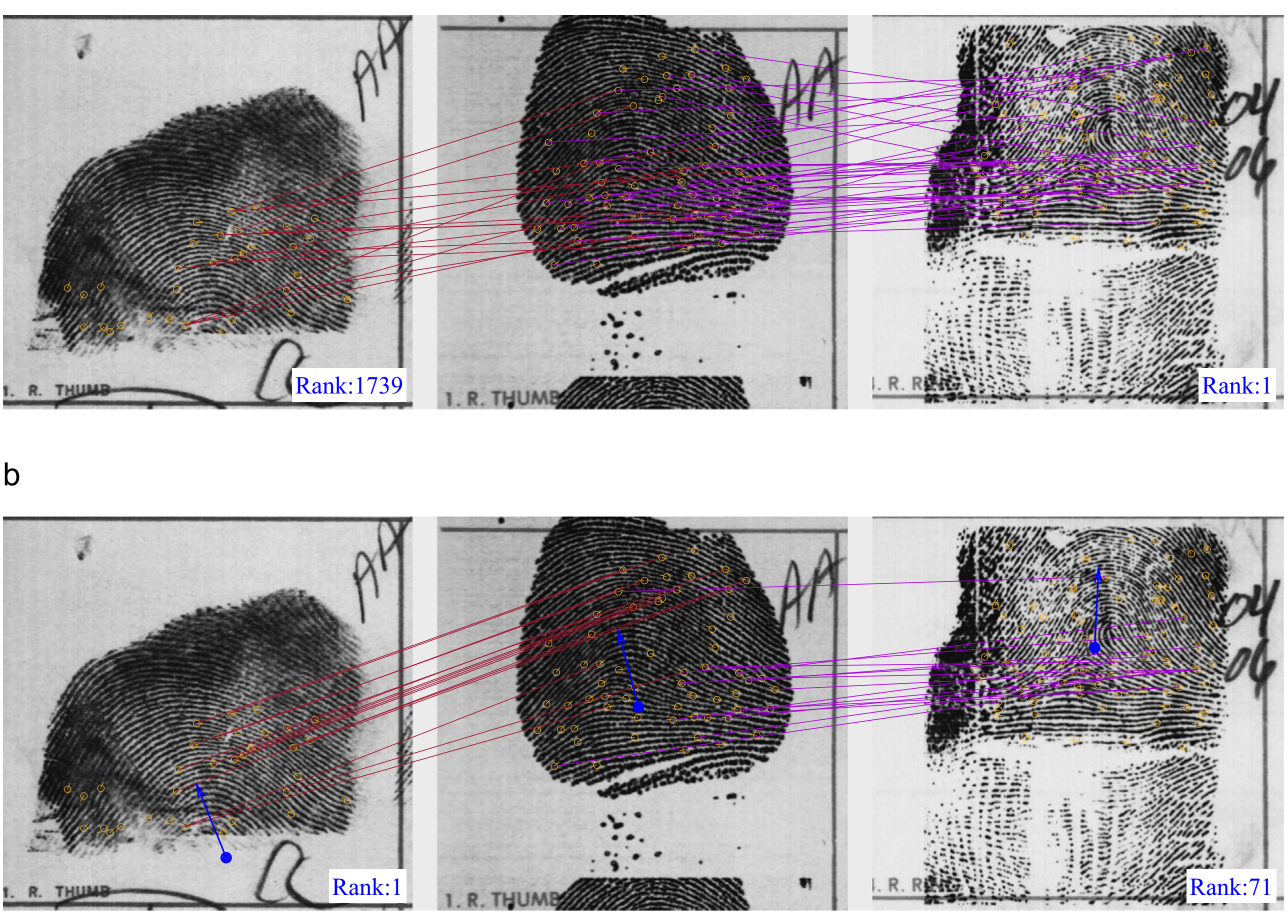

Fig. 1. Indexing results of MCC-LSH based fingerprint indexing algorithm [9] without/with pose constraint. (a) Indexing result with a loose constraint for translation and rotation (256 pixels and 45°, just the same with that in [9]). (b) Indexing result with a tight constraint defined by finger poses estimated by the proposed algorithm. The fingerprint in the middle column is query fingerprint, the left one is its mated gallery fingerprint, and the right one is the gallery fingerprint with highest score in the case of (a). Center point and direction (namely pose) of fingerprints estimated by the proposed algorithm are marked by circle and arrow, respectively. Matched minutiae are connected by lines. The ranks of gallery fingerprints are annotated on the bottom right corner of the images.