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Latent fingerprint identification using deformable minutiae clustering

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ABSTRACT

Automatic latent fingerprint identification is a useful tool for criminal investigation. However, the accuracy of identification reported in the state-of-the-art literature is low due to the distortion in latent fingerprint images. In this paper, we describe a new algorithm based on the use of clustering which is independent of the minutiae descriptors. The proposed technique improves the robustness of identification in the presence of large non-linear deformation which is associated with latent fingerprint images. The new algorithm finds multiple overlapping clusters of matching minutiae pairs which are merged together to find matching minutiae. Several experiments performed using latent fingerprint databases show that our proposed algorithm achieves higher accuracy than those presented in state-of-the-art literature. Moreover, the results show that the proposed algorithm is successful in dealing with the large distortion associated with latent fingerprints formed under the worst conditions.

1. Introduction

Latent fingerprints are among the most important clues used in law enforcement because of their uniqueness, permanence, and universality. Automatic fingerprint and palmprint identification systems are necessary in managing the millions of comparisons required to find a correspondence between a query latent fingerprint and the available impressions. For example the FBI's Integrated AFIS (IAFIS), which houses records of approximately 73 million known criminal subjects, receives an average of 700 latent search requests per day[1] from authorized law enforcement agencies. So the performance of these systems is crucial for solving crimes; the research community has made great efforts to improve the accuracy of these systems [2–15].

Researchers are interested in latent fingerprints for the following reasons: (a) their usefulness in criminal investigations and (b) the challenges related to the acquisition and processing of low quality and highly distorted images [16]. We can distinguish between intentionally produced fingerprints also called exemplar fingerprints, which are made under controlled conditions using specific materials or devices (either inked or digitally acquired) and latent fingerprints, which have been formed accidentally where natural secretions of sweat from human tissue have been left. Two issues cause complexity in the collection of latent fingerprints. They can appear on a variety of surfaces and it is necessary to lift the impressions according to very specific forensic protocols. The accidental formation and the difficulty experienced in retrieving them impact the nature of the latent fingerprints such that the quality is usually lower than that which is found in rolled or plain impressions [4,17] (see Fig. 1).

The low quality of the images and the large non-linear deformation in latent fingerprints make constructing accurate identification algorithms a challenge. The accuracy of algorithms used in latent fingerprint identification is moderate (54.0% rank-1 identification performance when tested on a large fingerprint database [19]). This contrasts with the high accuracy (99.0%) of algorithms used with rolled/plain impressions [20].

Different strategies are proposed to deal with the complexity inherent in latent fingerprint images; a recent review appears in

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[1] Statistics of 2012 [1].

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0925-2312/

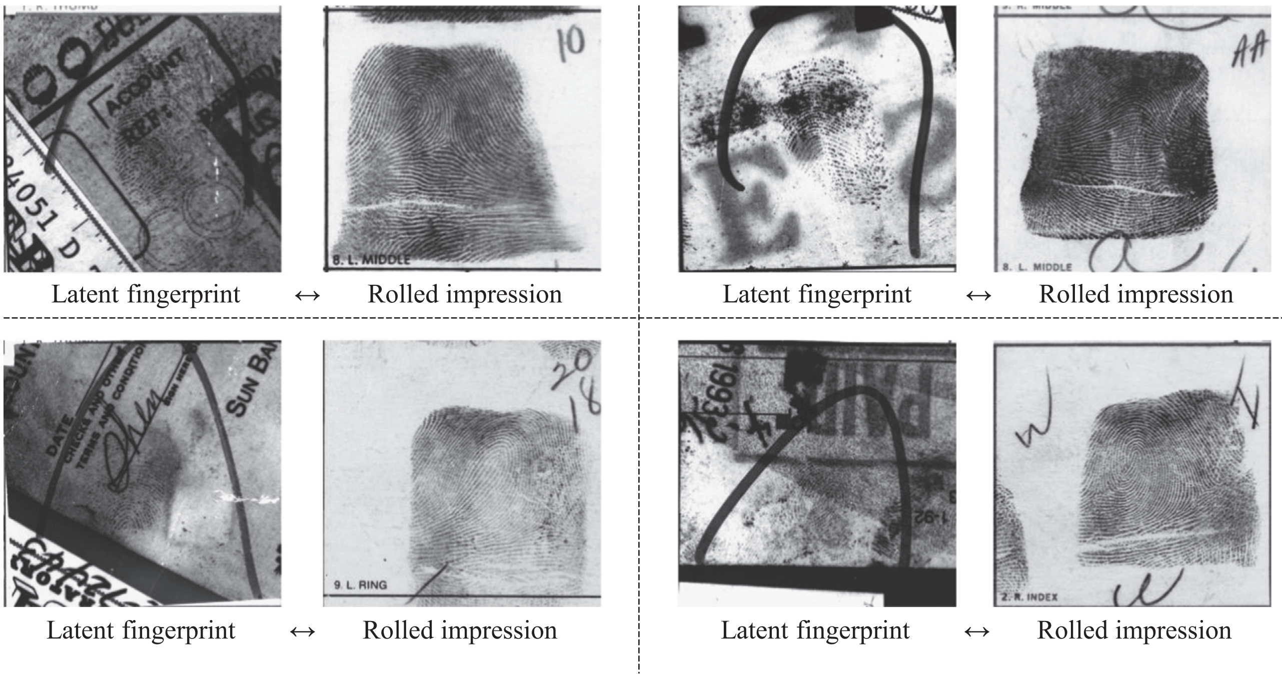

Fig. 1. Four examples of latent-rolled pairs of identified fingerprints from database NIST SD27 [18]. Notice that, unlike the rolled impressions, the latent fingerprints contain partial information and higher levels of noise.

[21]. Some authors [2,11,12] conclude, not surprisingly, that the accuracy of latent fingerprint identification is better when the features are extracted by human experts. Other reports [7–10,14] show that the accuracy of latent fingerprint identification improves when using other features such as ridge counts or orientation maps in addition to minutiae. A novel approach [3] improves the identification accuracy by using previously matched fingerprints.

Previous works [6,10–12] study the behavior of fingerprint verification algorithms in the context of latent fingerprint identification. However, as pointed out in [22], a good verification algorithm is not necessarily good for identification. That is why the current tendency is to create specific algorithms for latent fingerprint identification.

Previous algorithms developed specifically for latent fingerprint identification [8,14] propose novel solutions in dealing with the non-linear distortion present in latent fingerprint images. In order to match fingerprints at the local level, groups of minutiae are identified on the basis of neighboring minutiae located within a radius of 80 pixels. The best estimated 5 local matching minutiae pairs are then used to find matching minutiae at the global level. Relying only on the “best” 5 minutiae pairs for aligning fingerprints could cause the omission of several good alignments, especially in the presence of high distortions.

The Descriptor-based Hough Transform algorithm [3,5,7] is another recent algorithm proposed for latent fingerprint identification. DBHT (acronym used by the authors in [5]) uses Minutia Cylinder-Codes [23] to match fingerprints at the local level and performs fingerprint alignment through the Hough Transform. DBHT discretizes the transformation space in order to find the best 10 alignments. The discretization of the transformation space causes loss of information and the use of a fixed number of alignments could be insufficient to find all the necessary alignments.

Despite substantial efforts in minutiae-based latent fingerprint identification, algorithms achieve moderate accuracy (Table 1), even when using additional extended features (column “Extended features” according to previous terminology [9]).

Table 1
The rank-1 identification accuracy reported for state-of-the-art algorithms using the public database NIST SD27 [18]. Notice that some results cannot be directly compared because they were achieved using different background databases. The results reported in [24] should be read carefully because they were achieved by identifying 50% of the latent prints in the NIST SD27 database.

Algorithm	**Reference**	**Rolled impressions additional to database NIST SD27**	**Extended features**	**Accuracy**(%)
VeriFinger SDK	Yoon et al. [11]	0	No	~58.0
VeriFinger SDK	Yoon et al. [10]	27,000	No	~13.0
		27,000	Yes	~39.0
Bozorth3	Mikaelyan and Bigun [6]	0	No	47.0
k-plet		0	No	55.0
Descriptor-based hough transform (DBHT)	Paulino et al. [7]	2000	No	62.4
VeriFinger SDK	Sankaran et al. [24]	2000	Yes	48.0
COTS		2000	No	~13.0
Bozorth3		2000	No	~16.0
DBHT	Liu et al. [3] and Paulino et al. [5]	31,740	No	53.5
Neighboring minutiae-based descriptor-1 (NMD-1)	Jain et al. [14]	0	No	~63.0
		2000	No	~50.0
		0	Yes	~86.0
		2000	Yes	79.5
Neighboring minutiae-based descriptor-2 (NMD-2)	Jain and Feng [8]	29,000	No	34.9
		29,000	Yes	74.0

In this paper, we propose a novel clustering algorithm to improve the performance of popular minutiae descriptor matching algorithms for latent fingerprint identification. The aim of the algorithm is to deal with the most common distortions of latent