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Fingerprint Core and Delta Detection by Candidate Analysis

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Abstract

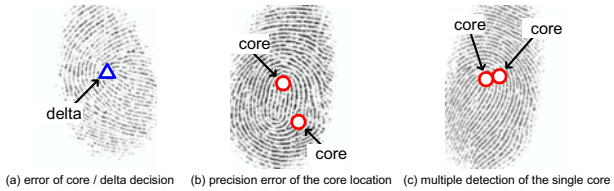
This paper presents a new reliable detection of core and delta in fingerprints by candidate analysis. The line search based method, which is one of the reliable approaches to detect core and delta, is improved aiming to realize the high positional precision and short computational time. In order to avoid the detection error, the three kinds of candidates, where the probability of core and delta existence becomes higher, are introduced. In the candidate analysis, the density of candidates is evaluated over the fingerprint. Also the structure of the extended relational graph generated from the directional image of the fingerprint is analyzed to find the number of core loop and delta loop. As same as the number of the core and delta loops, the connected candidate groups are picked up in the order of the candidate density. The center of each candidate group becomes core or delta. Based on several experimental results, the success rate of the core and delta detection can be achieved about 2 % improvement further than the line search based method against several public fingerprint databases. Furthermore it can be also achieved the 20 % reduction of the computational time.

1. Introduction

Fingerprint is used for the applications for wide ranges of personal identifications. One of interested applications is privileged access control for security places and personal belongings such as office and home. For such applications, the computational complexity to process identification should depend only on the selected security level. The idea of the fingerprint recognition algorithm should tolerate orientation, translation, elastic distortion of the input fingerprint [1][2][3][4]. Moreover, it should avoid applying the complicated algorithm in order to implement by embedded processors.

When the number of the register users at the fingerprint identification system becomes larger, the comparison number is tended to become larger. To reduce the computation time at the identification phase, it is necessary to classify fingerprints at the registration stage. It is known that fingerprint core and delta are referential points to classify fingerprints. If the reliable core and delta detection can be established, it may be easy to realize the reliable classification of fingerprints [5][6].

Poincaré method [7] is the most popular and practical approach to detect core and delta of fingerprints. This method estimates the directional image of the fingerprint with the smoothing process of ridge orientation. Poincaré method extracts singular points, i.e. core and delta, due to the estimation of the ridge orientation



(a) error of core / delta decision (b) precision error of the core location (c) multiple detection of the single core

Figure 1. Typical examples of detection errors.

difference between adjacent blocks. Since the algorithm of Poincaré method is simple, the computation overhead is rather small. However core and delta detection for noisy or low quality image is rather difficult to detect the singularities by Poincaré method. It may lead to the false detection because Poincaré method only uses the local feature of the fingerprint.

To improve the success rate of core and delta detection, a new detection by *line search based method* was proposed [8]. Since line search based method uses *extended relational graph* [9], which includes the global feature of the ridge structure, it can realize reliable detection of core and delta against poor quality fingerprint images. To realize precise detection both of core and delta, line search based method introduce two kinds of candidate models, which indicates the locations where the probability of core and delta existence becomes higher. The positional precision error, recognition error between core and delta, and multiple misdetection error (as shown in Fig. 1) can be reduced by including the analysis using two candidate models. Though the reliable core and delta detection can be achieved by line search based method, there still remains the problem that the computational complexity becomes higher than Poincaré method.

This paper is intended to report the improved reliable core and delta detection, aiming to achieve both of higher detection rate and fast computation by the candidate analysis. Based on several experiments, the computational time can be achieved the 20 % reduction by the proposed approach, even though the success rate can be achieve the 2 % improvement than line search based method.

2. Detection by Candidate Analysis

2.1. Overview of Line Search based Approach

In line search based approach [8], the directional image is generated from the input fingerprint image. The extended relational graph is generated from the directional image. The direction difference around the pixel on the segment boundaries is evaluated to extract the core candidate and delta candidate. Fig. 2 shows two kinds of candidates, which have high possibility to exist core or delta. Fig. 2 (a) shows *core candidate model*, and

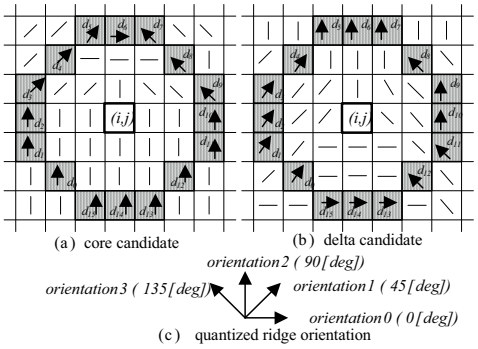


Figure 2. Core and Delta Candidate Models of Poincaré Method .

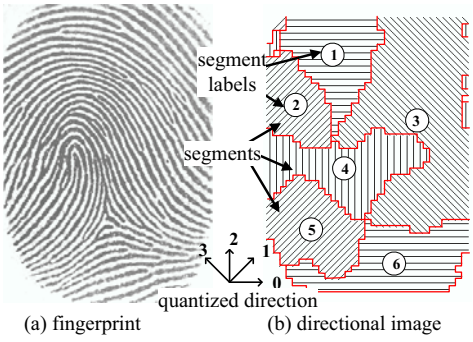


Figure 3. Example of Directional Image Generation.

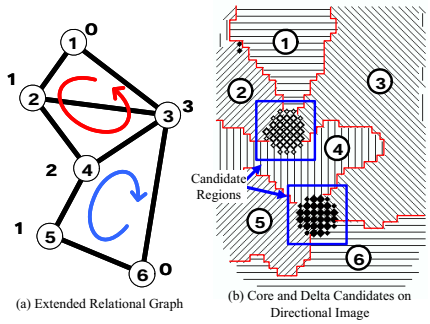


Figure 4. Graph Analysis and Candidate Region Detection in Line Search based Method.

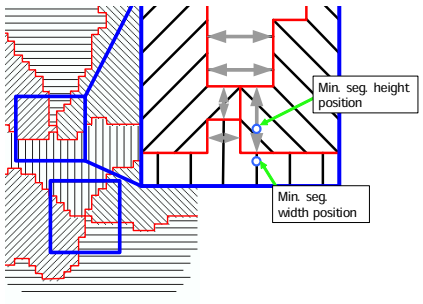


Figure 5. Core and Delta Detection by Line Search.

Fig. 2 (b) shows *delta candidate model*. When the direction difference around the specified pixel becomes more than 2, and the direction is counter clockwise rotation, it can be core candidate. When the direction difference becomes more than 2, and the direction is clockwise rotation, it can be delta candidate.

Fig. 3 (b) is an example of the directional image, generated from the actual fingerprint Fig. 3 (a). The extended relational graph, shown in Fig. 4 (a), is generated from the directional image Fig. 4 (b), which shows the features of the distribution of the ridge direction and the adjacency of each segment [9]. Due to the graph analysis by the depth first search, the core loop and the delta loop will be extracted from the extended relational graph if there are. The rectangle region, which contains segment boundaries along the core loop or delta loop, and in which the density of core and delta candidate becomes higher than the specified threshold value, is defined as the candidate region, like Fig. 4 (b). Due to the extended relational graph analysis, both of core loop and delta loop will be extracted if there are. The one directional line scan search is processed both of horizontal direction and vertical direction in each candidate regions, aiming to find the location where segment width or height becomes the minimum. An example of search result is shown in Fig. 5. The precise core and delta location are calculated as the averaging point of these minimum locations.

2.2. Overview of Core and Delta Detection by Candidate Analysis

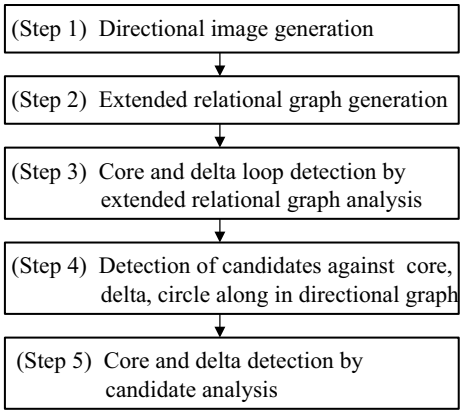


Figure 6. Overview of proposed approach.

The proposed approach is the improved method of line search based approach. The overview of the proposed approach is shown as Fig. 6. The first step is the directional image generation from the input fingerprint. The directional image is separated into 8 x 8 blocks. The ridge direction is quantized in to 4 steps by sliding the directional masks over the fingerprint image. The block direction is decided as the most similar quantized direction inside of the block. The blocks, which are placed adjacently and have same direction, are combined together to construct the segment. Fig. 6 shows one of examples to generate the directional image and its segmentation result.

In the step 2, the extended relational graph is generated from the directional image [8][9]. Each node in the extended relational graph is corresponding to each segment in the directional image. Each edge in the extended relational graph shows the adjacent relationship between segments. When two segments are placed adjacently, the edge is bridged between corresponding nodes.

In step 3, every core loop and delta loop are extracted by the extended relational graph analysis. The depth first search against the extended graph is adopted to find every core loop and delta loop.

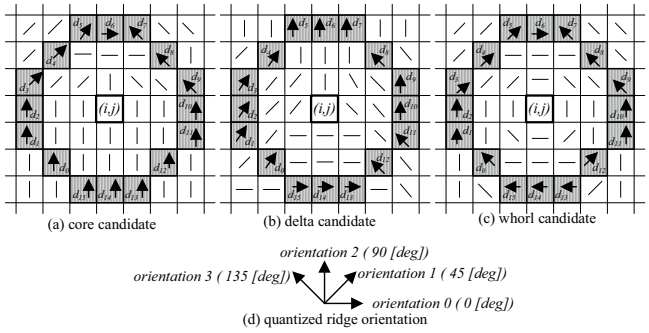


Figure 7. The three candidates in proposed approach.

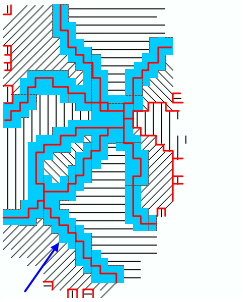
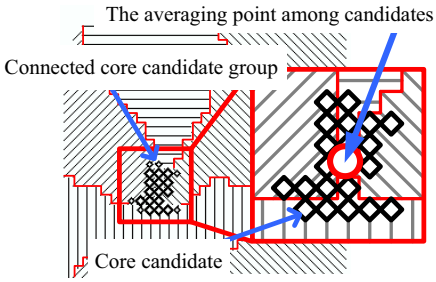
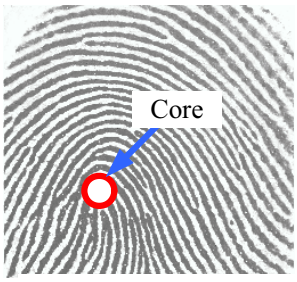


Figure 8. Example of search areas to find candidates in proposed approach.



(a) Candidate rectangle (core)



(b) Example of the detection result

Figure 9. Example of the detection result by proposed approach.

In the step 4, three kinds of candidates, i.e. core candidate, delta candidate, and whorl candidate, are extracted from the directional image. The direction difference between neighbor blocks between hatched pixels in Fig. 8 along segment boundaries is evaluated to extract the core candidate, delta candidate and whorl candidate.

When the direction difference becomes more than 2, and the direction is counter clockwise rotation, it can be core candidate. When the direction difference becomes more than 2, and the direction is clockwise rotation, it can be delta candidate. The whorl candidate is one of the special patterns of the core candidate. The actual example of each candidate is shown in Fig. 7.

To prune the search space, only the locations around boundaries, which are located between segments belonging to the core loops or delta loops, are evaluated the directional difference to find these candidates. The highlighted boundaries between segments in Fig. 8 show actual examples of search area to find such candidates.

In the step 5, the candidate analysis is performed to estimate the connectivity between candidates. The candidates are grouped based on their connectivity. The connected candidates are structured one candidate group. The candidate groups are picked up in order of their density as same number as both of the core loops and delta loops. The averaging point of the candidate group becomes core position or delta position. Based on the kind of candidates, it is easy to specify the candidate type. Fig. 9 is one of actual example of core detection by proposed approach. The proposed approach is expected core and delta, realizing fast computation by adopting the candidate analysis instead of line scan search to find the core and delta position,

3. Experimental Results

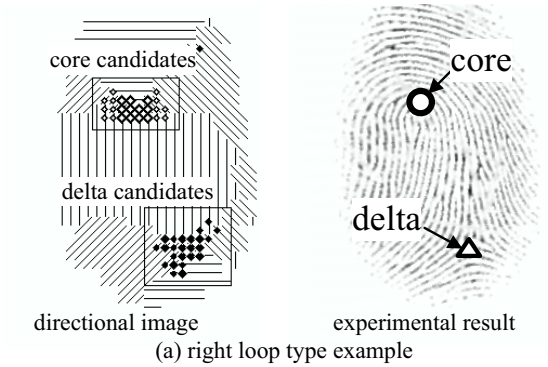
To evaluate the proposed approach more precisely, we apply our approach against 4 types of fingerprint databases. First one is our original database which contains 224 fingerprint samples with the size 224 x 288. FVC2000, FVC2002, FVC2004 are very famous public fingerprint database each of which contains 800 samples [10]. FVC2004 database includes rather more poor quality fingerprint images than others.

Fig. 10 shows experimental results of the core and delta detection against 4 typical fingerprint classes in FVC2004 database by the proposed approach. Fig. 10 shows that the reliable core and delta detection can be succeeded.

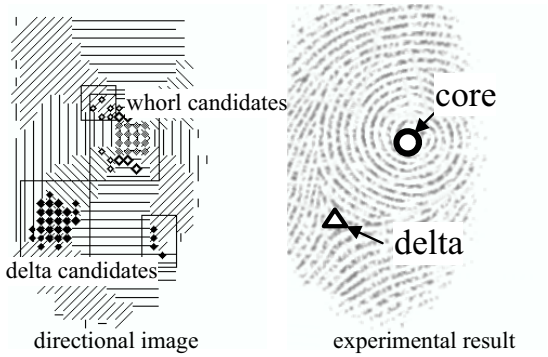
The success rate of core and delta detection for each database is summarized in Table 1. To compare with other approach, Table 1 also contains the results by line search based method [8]. The processing time is measured using 3.2 GHz Pentium 4 Windows PC. The proposed approach can be succeeded to realize about 2 % improvement in the success rate. Furthermore it can be also succeeded to realize about 20 % reduction of the computational times.

4. Conclusion

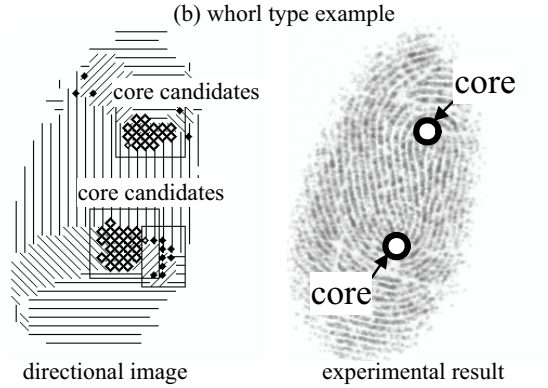
This paper shows a new reliable core and delta detection by the candidate analysis. To realize reliable extraction of core and delta, three kinds of candidates, i.e. core candidate, delta candidate, and whorl candidate are introduced. In the candidate analysis process, the connectivity of each kind of candidates is analyzed and picked candidate groups up based on the core and delta loop numbers in the extended relational graph. The core and delta location can be computed as the averaging point of each candidate group. By the pruning of the



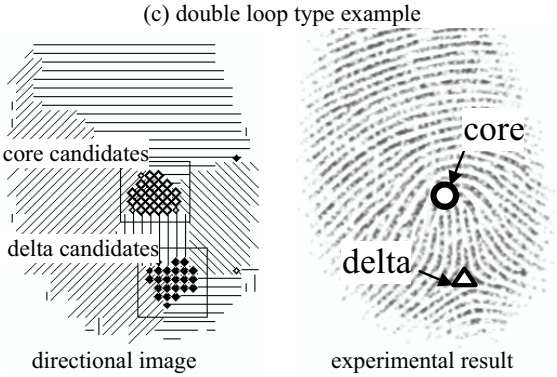
(a) right loop type example



(b) whorl type example



(c) double loop type example



(d) tended arch type example

Figure 10. Experimental results by proposed approach.

Table 1. Summary of Experimental Results

Fingerprint Databases	Line Search based Method [8]		Proposed approach	
	Success rate [%]	Processing time [sec]	Success rate [%]	Processing time [sec]
Original DB[11]	97.3	0.295	97.8	0.222
FVC2000 DB4[13]	97.1	0.352	97.1	0.249
FVC2002 DB4[13]	97.3	0.466	98.3	0.365
FVC2004 DB4[13]	94.6	0.442	96.0	0.368

search space, and by refining algorithm to calculate the core and delta location, it can be succeeded to realize 20 % reduction of the processing time even though the success rate of detection is achieved 2 % improvement.

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