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A New Approach for the Fingerprint Core Detection using the Modified Relational Graph

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Abstract– This paper describes a new approach to detect a fingerprint core location using the modified relational graph, which is generated by the segmentation of the ridge directional image. The modified relational graph presents the adjacency between segments of the directional image, and the boundary information between segments of the directional image. The boundary curves generated by the boundary information in the modified relational graph is approximated the straight lines. The fingerprint core location is calculated as center of the gravity in the points of intersection of these approximated lines. Experimental results show that 90.8 % of the 130 fingerprint samples are succeeded to detect the core location.

1. Introduction

At first, fingerprint identification has been used for the legal purposes such as the crime investigation. Now, it is used for the applications which need a wide range of verifications. One of interesting applications is privileged access control for security places and personal belongings such as office, home and etc. For these particular applications, the algorithm needs only limited fingerprint database and its computational complexity should depend only on the selected security level. The idea of the fingerprint recognition algorithm should tolerate orientation, translation, elastic distortion, and noise of the input fingerprint. Moreover, the algorithm should not be too complicated in order to implement in a stand-alone hardware.

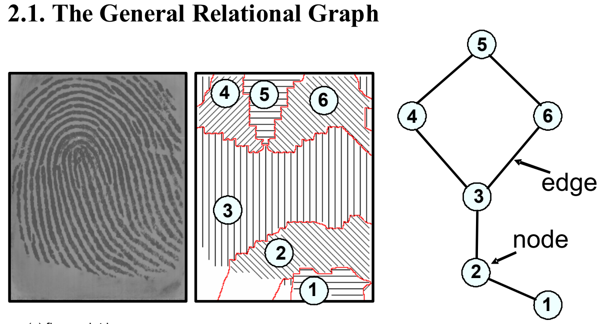
A real time fingerprint matching for large databases should have two stages : coarse stage and fine stage[1]. The purpose of the coarse stage is to reduce the search space during matching process by detection of the high level features such as singular point feature like core or delta points. With these singular point features, fingerprints can be classified into 6 whorl, and twin loop. It is known that the exclusive classification is effective to reduce the search space for fingerprint matching. Moreover the core and delta points become the reference points to detect the orientation, scale and translation of the input fingerprint images, aiming the reduction of the computational time in the fine stage.

This paper represents a new approach to detect the fingerprint core location for the coarse stage using the modified relational graph, which is generated from the directional segmentation of the fingerprint image. The general relational graph proposed in Ref. [2] has only the adjacent relationship between directional segments. The modified relational graph, which is proposed in this paper, has additionally the boundary information between segments and the direction of each segment. According to the additional information, the core location of the fingerprint can detect easily by analyzing the modified relational graph.

The proposed approach is evaluated the precision of the core location for 130 fingerprint samples and the core location for the 90.8 % samples of the fingerprints is correctly detected.

2. The Core Detection using the Modified Relational Graph

2.1. The General Relational Graph



(a) fingerprint image (b) directional image of the fingerprint (b) general relational graph

Fig.1 The scheme of the general relational graph

The scheme of the general relational graph generation is shown in Fig.1[2]. The basic idea is to perform a ridge directional image partitioning into several homogeneous regular shaped regions, which are used to build general relational graph summarizing the fingerprint macro features. The procedure to generate the general relational graph is divided into the four stages, i.e. the computation of the directional image is generated according to the distribution of the ridge direction in the fingerprint image. The segmentation of the directional image is grown up when the direction of the adjacent block is same by assigning same direction label. Fig.1 (b) is generated from the fingerprint as shown in Fig.1 (a). It also shows one of the segmentation results of the fingerprint image. The general relational graph is constructed from the segmentation result according to the relationship between segments. Fig.1 (c) is one example of general relational graphs, which is generated from Fig.1 (b). In case that the quantization of four directions is adapted, the ridge directional image is computed by sliding the four normalized direction mask over a binary image of the fingerprint. A dynamic clustering algorithm is adapted to segment the directional image aiming to generate partitions as homogeneous as possible. The cluster algorithm works by minimizing the variance of the element directions within the regions and, simultaneously, by maintaining the regularity of the region shape. Starting from the segmentation of the directional image, a general relation graph is built by creating node for each region and an edge for each pair of adjacent region. By appropriately labeling the nodes and edges of the graph, a structure which summarized the topological features of the fingerprint and which is invariant with respect to displacement and rotation, is generated as a general relational graph.

The general relational graph indicates several macro features of the fingerprint, such as the topology of the ridge shape. An inexact graph matching derived from [3] is used to calculate the distance vector between graph and each class prototype graph. The distance is considered to be a continuous classification of the fingerprint, since it describes how close the fingerprint to each class. If the application needs to assign a fingerprint to a single class, the vector obtained can be given as input to a general purpose classifier. It is worth noting that this technique does not require any position aliment or normalization and, in principle, can be directly used for the classification of partial fingerprint.

2.2. The Modified Relational Graph

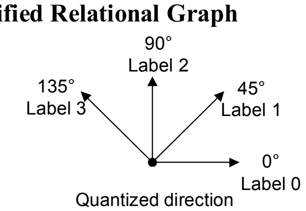


Fig.2 The quantized direction for the ridge direction

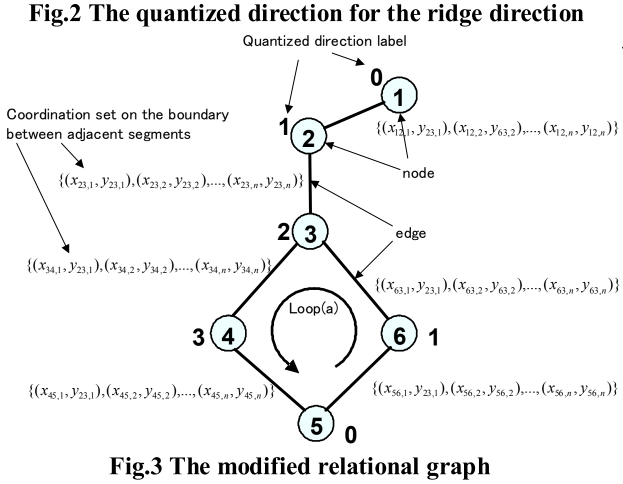


Fig.3 The modified relational graph

A preliminary analysis of the experimental results produced by the general relational graph approach described in section 2.1 pointed out that some problems arise from the difficulty in obtaining analogue segmentation from similar directional images. In fact, although the greedy clustering algorithm adopted usually produces a good segmentation, it is too influenced by local ridge line orientation changes, by the starting point of the clustering routines, and by some specific parameters. In such cases, several problems are encountered by the inexact graph matching algorithm in finding the hidden similarities. Moreover, the fingerprint core location, which becomes one of the important reference points for the identification, cannot be calculated because the general relation graph doesn't have the boundary information of the each segment.

In this paper, the modified relational graph is proposed, aiming to avoid the confusion caused by the hidden similarities of the general relational graph. The modified relational graph inherits the all features of the general relational graph. It is additionally included the information of the ridge direction and segment boundaries. In the modified relational graph, each node has the quantized direction number, and each edge has the information of the coordination set, which are includes is the boundary curves between segments in ridge directional image. The direction number of each node is quantized into four normalized direction as shown in Fig.2.

An example of the modified relational graph is shown in Fig.3. The direction label of each node is changing monotonously one by one along the loop. This example of the modified relation graph shows that the directional inclination of each adjacent segment shows that 45 ° are changing monotonously. When the sub-tree of the modified relational graph includes the direction set like the Loop (a) shown in Fig.3, it can find that the fingerprint contains the ridge shape like a semicircle (i.e. an arch). Generally it can be detected that the fingerprint includes an semicircle pattern in the local ridge shape, when there are whole values of the quantized ridge direction along the sub-tree of the modified relational graph, and the each difference of the direction between the adjacent nodes is just 45° (in case that quantization number of directions is 4.).

2.3. Detection of Fingerprint Core Location

In previous section, the basic idea of the semicircle detection approach using the modified relational graph analysis is proposed. In this section the core detection approach will be represented.

When the fingerprint contains an arch, loop or a whorl like Fig.4 (a), the local ridge shape is similar to a semicircle. When the local ridge shape is assumed as a complete circle like Fig.5, the boundary between adjacent segments of the directional image becomes a almost straight line Fig.4 (b) shows one of examples. In such case, the core (center of the loop, whorl or arch) of the fingerprint is located on the cross point of straight lines, which are generated from the boundaries curve by the linear approximation.

Since the coordination set on each boundary between segments is stored as the edge information (Fig.3), it is

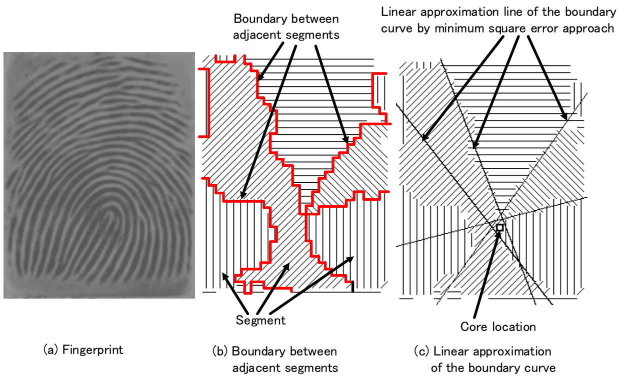


Fig.4 Detection of the core location

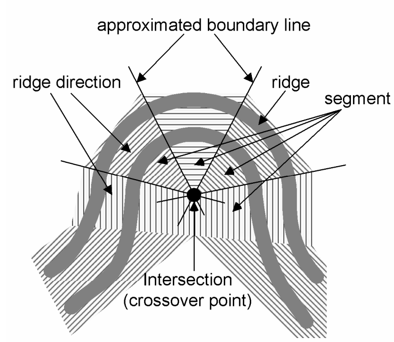


Fig.5 An example of ridge shape which contains a complete semicircle.

easily generated the minimum square error lines. When the local ridge shape around the arch, loop or whorl of the fingerprint becomes an incomplete circle, straight lines of the boundaries by minimum square error approximation cross over on several points like Fig.4 (c). Almost all cross points are located very closer when the local ridge shape is almost similar to a circle. In this paper, the core location is detected as the averaging point of such cross over points. The overview of the fingerprint core detection algorithm is shown is Fig.6.

3. Experimental Results

The proposed approach to detect the core location of the fingerprint is adapted with respect to 130 fingerprints image. The sensor is Beyond LSI Co.'s fingerprint sensor. Fig.7 shows the result of our approach. The size of fingerprint image is 224 x 288.

Fig.7 (a) and Fig.7 (b) is the loop classified fingerprint. According to the modified relational graph, the semicircle pattern is detected. By the linear approximation of the boundary curves, the core location is detected as the center of the cross points between lines which are laid between adjacent segments as shown Fig.7 (a) and Fig.7 (b). Fig.7 (c) is the double loop classified fingerprint. Analyzing the modified relational graph, two semicircles are detected. Therefore double cores are detected like Fig.7 (c). Fig.7 (d) is the whorl classified fingerprint. In this case, there are also double semicircles are detected. The double cores are detected as shown in Fig.7 (d). In

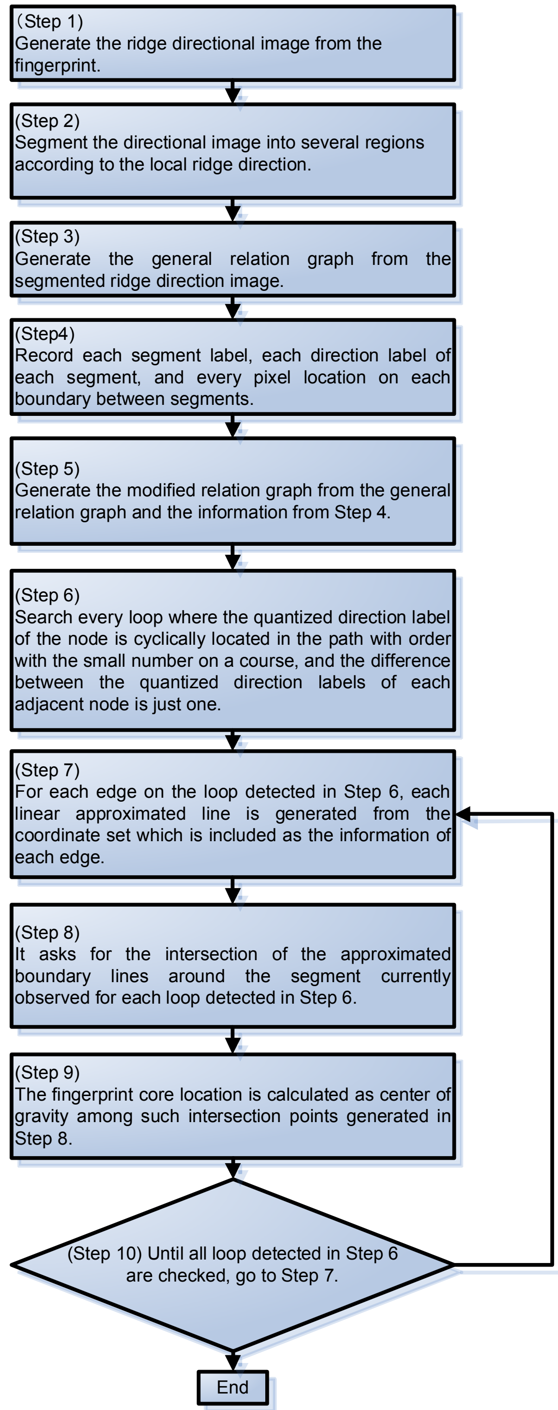


Fig.6 The overview of the fingerprint core detection

case that there is the degradation around a core on the fingerprint, it can be detected the correct core location by using whole area of the directional image information, as shown in Fig.7.

All results of this method are preprocessed to refine the degradation of input images. It is assumed that it is succeed if the fingerprint core can be detected within the

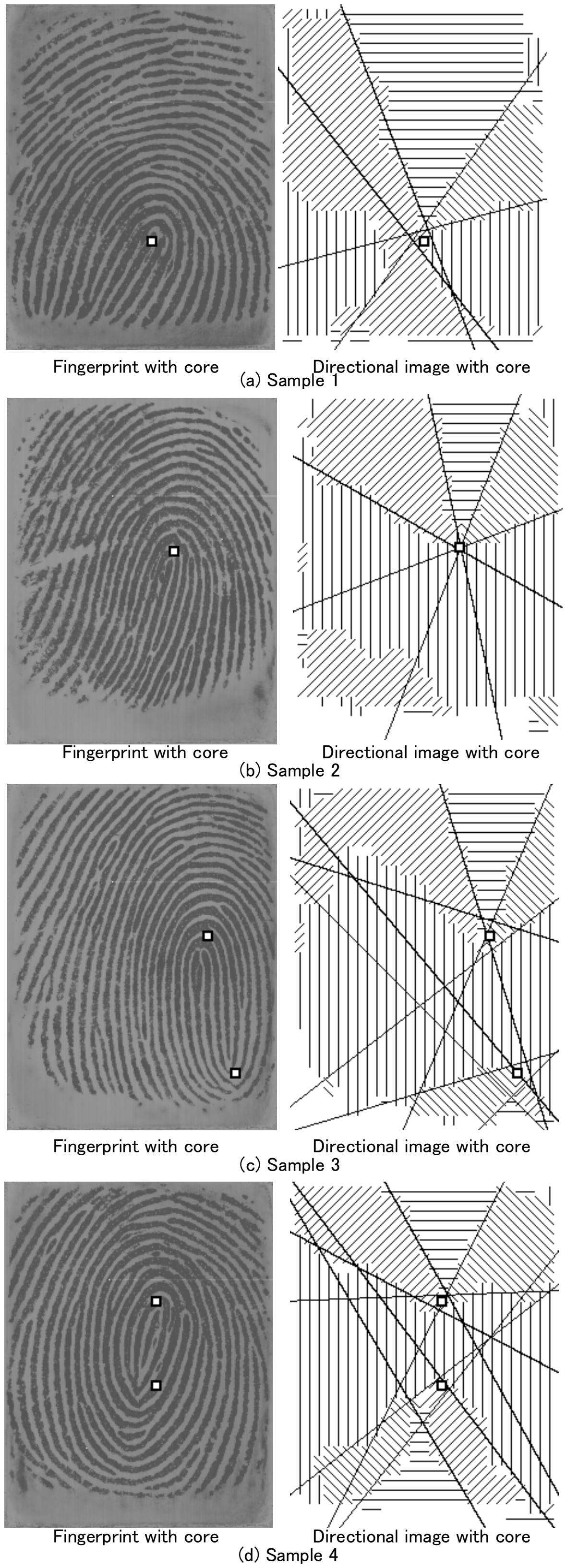


Fig.7 Examples of experimental results

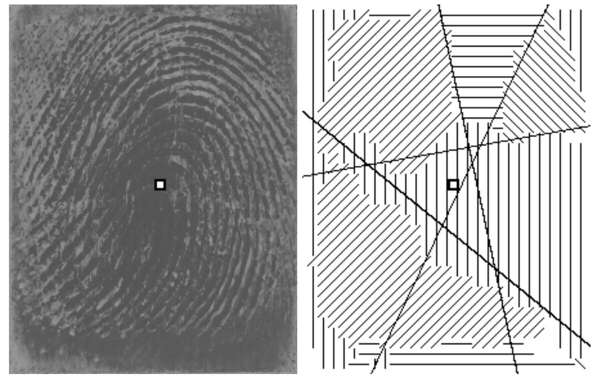


Fig.8 Degraded fingerprint example

error 16 pixels around the core point, which was confirmed by the human experience. According to our approach 90.8 % of the 130 sample fingerprint images can be detected the core location successfully. It is observed that the degradation of the fingerprint image becomes the cause not to detect the core locations as shown in Fig.8.

The computation time by Pentium III 1 GHz Processor is distributed from 0.39[sec] to 0.45[sec] for 130 samples, and the average value is about 0.42 [sec].

4. Conclusions

This paper proposes a new core detection approach for fingerprint images using the relational graph. To revise the problem of the general relational graph approach, the modified relational graph is proposed. The core location is detected at the averaging point of the cross over points of the straight lines, which are generated using the boundary curve in the directional image. 90.8 % of the 130 samples of the fingerprints are succeeded to detect the core locations. The average of the computational time is 0.42 [sec] by Pentium III 1 GHz Processor. Even though there is the degradation around the core in the original fingerprint image, it can be detected the core location. This approach is only available against loop, whorl and arch. The detection of delta location of the fingerprint is the future work.

Acknowledgments

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