Study on the Basic Characteristics and Change Rules of Fine Point Lines in Fingerprints

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Abstract: At present in our country, the automatic fingerprint identification system plays a great role in investigating and solving cases, but technical improvements still need to be made in some places. Current automatic fingerprint identification systems are based on level 1 and level 2 features of fingerprints. But for fingerprint experts, in addition to level 1 and level 2 features, level 3 features are also needed in manual inspection and identification. If these features can be introduced into the identification system, the performance of system will be further improved. The fingerprint fine point line is a typical three level feature, but the basic theories about fine point lines are not perfect at present. Therefore, this paper studies the basic characteristics and the changing rules of fine point lines, and established a new identification method on that basis, which can provide a reference for the establishment of the next generation fingerprint automatic identification system.

1. Introduction

In practical cases, incomplete fingerprints are often extracted. If the fingerprint area has many minutiae features, it will be easy to compare automatically. However, some fingerprints have very few detailed features in a certain area, which brings great difficulties to the automatic identification and manual comparison. If there are fine point lines in the sample, important information will be provided for inspection and identification. Figure 1 shows that process. After enlarging the area in the red box of (a), we can get the image of (b). We can find that there are fewer detailed features in this area, and it is difficult to identify that fingerprint. However, there are many fine point lines in this area. Red dots are marked at minutiae and green dots are marked at fine point lines. As shown in Figure (c), there are 7 minutiae and 27 fine point lines. If the system can extract fine point lines smoothly and use them in the fingerprint comparison, the recognition accuracy of the system will be improved.
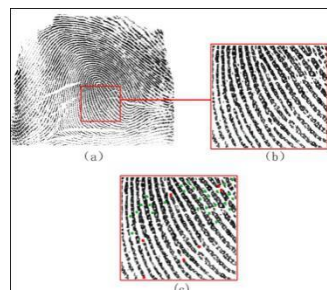

Figure 1. (a) is the complete fingerprint image, and the region in the red box is enlarged to obtain (b).

Minutiae in figure (b) are represented by red dots while fine point lines are represented by green dots; figure (c) is obtained.

2. Extraction and Matching of Fine Point Lines

Although fine point lines have high recognition value, only accurate recognition methods can help them to play a role. Yi Chen and A. K. Jain of the United States have published a paper on the identification of fine point lines. The core idea of its extraction algorithm is to use the symmetry of fine point lines. Fine point lines are more symmetrical than normal ridges and valleys because they are located between normal lines and manifest themselves as isolated points or fine lines. The basic process of extracting fine point lines is shown in Figure 2. The picture of (a) is a part of the fingerprint. After skeletoning the small plough groove, picture (b) is obtained as the skeleton of the small plough groove. The picture (c) is the local phase symmetry image obtained by wavelet processing. It can be found that small plough groove is also detected. If we overlap images of (b) and (c), the white areas shared by the two graphs will be the fine point lines, as shown in Figure (d). Comparing (a) (d), we can find that this method can extract small points and coherent lines accurately.

(a) The local region of the fingerprint (b) Skeletoning the small plough groove area (c) The local phase symmetry (d) Fine point lines extracted
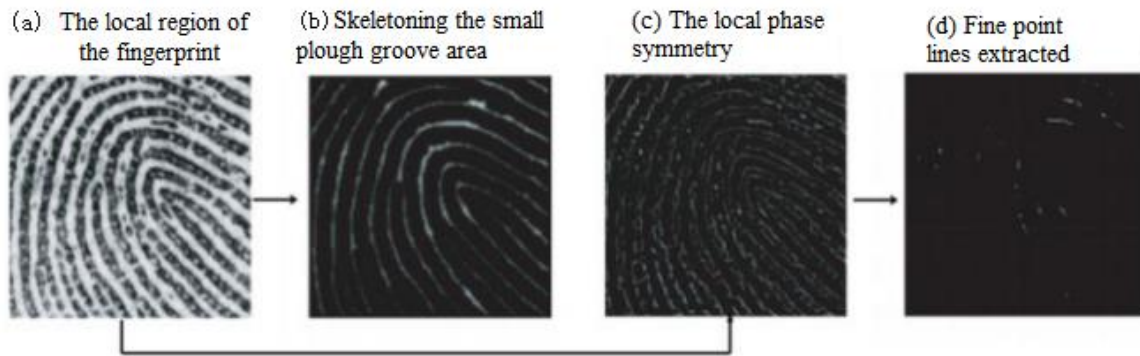
Figure 2. The basic process of extracting fine point lines

In the matching process, the result which only compares minutiae and the result which compares minutiae and fine lines are adopted. The matching of minutiae is carried out through the existing matcher. For fine lines, the centroid of the gray image of the fine line is calculated first, so as to obtain the position and direction of the fine line, and match the image accordingly. The experimental results show that result which compares minutiae and fine lines has obviously higher Genuine Accept Rate and lower False Accept Rate than the result which only compares minutiae.

The experimental results show that the proposed method can improve the performance of the current recognition system. However, the fingerprint samples used are randomly collected; the changes of fine lines are not taken into account. But fingerprint patterns are affected by the pressing pressure. If we do not consider these changes, the recognition rate of the system will be reduced. According to previous experiments, with the increase of the pressing pressure, fine lines have three changes. New fine lines are produced; fine lines become longer and wider; unconnected fine lines may be linked. The first change has little effects on the experimental results of the aforementioned method, because the change of feature points is a common problem in the fingerprint comparison. The system only calculates the number of feature points that can be matched, and ignore non-matching features. The second case does not produce great effects on the experimental results, because the matching of fine points is based on the centroid of the gray image. Although the fine lines become longer and wider, their positions do not change significantly, so the position of centroid will basically remain unchanged. If the third change occurs, the aforementioned method will have disadvantages. In the case of less pressing pressure, fine lines appear as discontinuous points, and the number of fine lines extracted is the number of fine points. If the pressure increases, two or more fine lines may be connected to form a feature. As shown in Figure 3, the fine lines in the red circle are four isolated points when the pressure is low. When the pressure increases, they become two lines. If using the recognition method previously mentioned, as shown in Figure 4, the number of extracted fine lines will be changed from four to two. Then the number and location of centroid of the fine lines also change, so the fine lines in this area cannot be matched. Therefore, when fine line changes from isolated points to continuous lines, the system cannot realize accurate
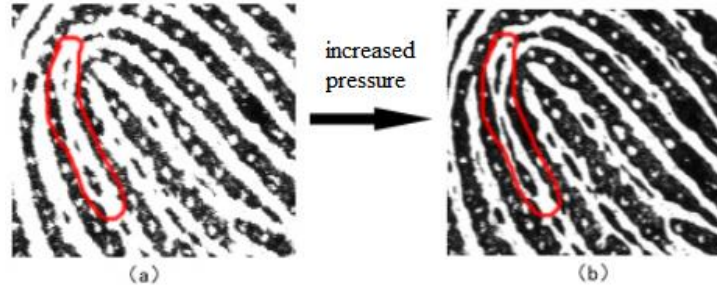
matching.

Figure 3. The fine lines in the red circle are four isolated points when the pressure is low. When the pressure increases, they become two lines.
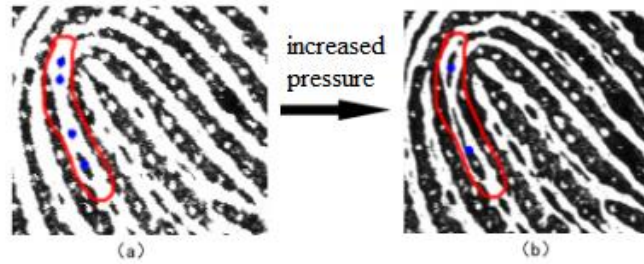

Figure 4. Using the recognition method previously mentioned to mark the centroid of fine lines. When the pressure increases, the number of centroid changes from four to two. The locations of centroid also change.

According to the previous pressure test, it is found that the patterns of fine point lines are obviously affected by the pressure. Therefore, the method of automatic recognition should be adapted to the changes of fine lines. The identification method proposed by Yi Chen and A K Jain should be further improved.

After a lot of observations, it is found that in the case of fine lines changing from discontinuity to coherence, the probability of connecting between two adjacent fine lines is higher, while the cases of three or more fine lines connecting into thin lines are relatively less. In order to reduce the workload of the system, we mainly consider the former changes to improve the identification method. In this paper, a method of second centroid comparison based on local phase symmetry is proposed. The basic idea of this method is to extract fine lines based on local phase symmetry, and calculate the centroid of the gray images of fine lines. The match is carried out based on the position and direction of centroid. If the matching is successful, the result will be recorded. If the matching fails, the system will calculate the value of d, namely the distance between p_1p_2, the centroid of two adjacent fine lines in the same small plough ditch. If d is greater than m (m is a set value), the system will stop matching. If d is less than or equal to m, the figure composed of two fine point lines is regarded as an image. The position and direction of its centroid, p, are calculated. The matching is conducted on the basis of p. (The matching effect of fine point lines in the red circle of Figure 4 after taking the centroid for the second time is shown in Figure 5. The red dot is the centroid taken in the second time.) If the match is successful, the result will be recorded; if the match fails, the match will be terminated and the result will be output.
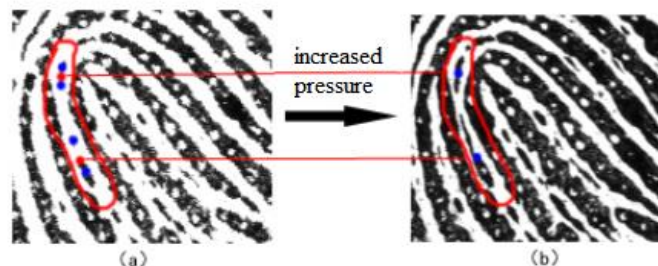

Figure 5. The red dot is the new centroid taken for the second time.

The value of d in the figure is the value obtained by observing the changes of adjacent fine point lines. When d is less than or equal to 0.5mm, with the increase of pressure, two adjacent fine points are easy to be connected. When d is more than 0.5mm, the possibility of connecting two fine points is very small. In order to ensure the efficiency of the system, these fine points will not be processed for the second time.

3. Fingerprint Recognition Based on Integrating Level 2 and Level 3 Features

At present in China, the automatic fingerprint recognition system for police is based on detail feature comparison. This method first extracts the starting point, the end point, the bifurcation point and the junction point of the ridge, and then matches these points. For a fingerprint extracted on the spot (i.e. the sample), the investigators manually calibrate its detailed features, and input the calibration results into the fingerprint automatic identification system. Then the computer automatically retrieves and compares the collected fingerprint with fingerprints in the database; the system outputs the matching set with candidate fingerprints according to matching scores from high to low. Afterwards, investigators manually compare these fingerprints in the candidate fingerprint set with the sample. The process is shown in Figure 6. In the case of small scale of fingerprint database, this method can achieve good matching accuracy. However, with the increase of the fingerprint database (some of which have reached the scale of tens of millions), the recognition accuracy of the system declines. In addition, some fingerprints in the scene are incomplete. These fingerprints contain limited minutiae, which put forward higher requirements for the hardware conditions and identification methods of the system.
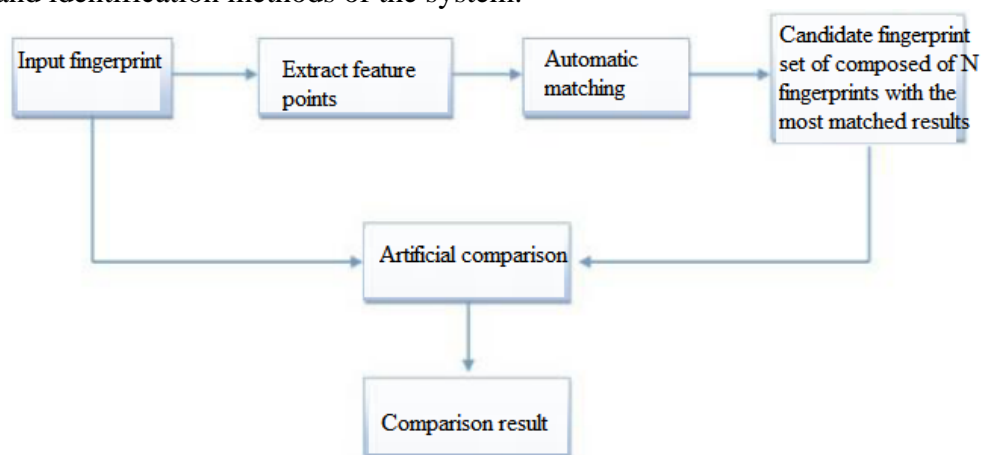
Figure 6. The basic working process of fingerprint automatic identification system for police

Compared with minutiae, the level 3 features of fingerprint contain more abundant information. If there are not enough minutiae in fingerprint, it will be difficult to identify the fingerprint by relying solely on level 2 features. If the abundant level 3 features in fingerprints are used, it will be easier to match the sample with fingerprints in the database. With the development of the fingerprint acquisition technology, fingerprint acquisition technology with 1000ppi high resolution ratio has entered the commercial field. Moreover, the technology of fingerprint display and extraction is constantly improving. The level 3 features of fingerprints on the surface of smooth objects can be better displayed through 502 and other appearing techniques. The conditions of fingerprint recognition through level 3 features are gradually mature. With the continuous expansion of the capacity of the fingerprint database, its application value will become increasingly significant. Therefore, this paper proposes a fingerprint recognition method that combines level 2 and level 3 features.

If there are abundant level 2 features in fingerprint, the traditional identification method has the advantages of saving storage space and searching time. After adding level 3 features to fingerprint information, the retrieval accuracy can be improved, but the retrieval time should also be taken into account.

Firstly, after acquiring fingerprints on the spot, it is necessary to mark minutiae and level 3 features of fingerprints. Then, for the fingerprint images input, the fingerprint recognition system needs to process them according to following procedure. First, the number of minutiae in the input fingerprint image should be calculated. If the number of minutiae is less than n (the value of n can be set according to the specific situation), the system will directly search and compare the fingerprint with images in the database according to level 2 and level 3 features. Otherwise, images in the fingerprint database will be screened according to minutiae features. After the preliminary screening, N1 fingerprints (more than 2000) are selected as candidate sets according to matching scores from high to low, and then fingerprints in the candidate set are retrieved and compared according to level 2 and level 3 features. After comparison -- the results obtained are accurate in most cases-- the N2 (less than 10) fingerprints are compared manually.

The advantage of this method is that for most fingerprints, it does not reduce the screening efficiency, but improves the accuracy. For incomplete fingerprints with fewer details, it reduces the screening efficiency. But for some important cases, it is more important to improve the accuracy. In addition, the fingerprint resolution ratio of the current police fingerprint database is unified at 500 ppi. Under this resolution, the level 3 features are very ambiguous and difficult to identify. It takes some time to build 1000ppi fingerprint database. This recognition system can be compatible with 500ppi and 1000ppi fingerprints, and can upgrade AFIS system without affecting the normal work of public security organs.

4. Conclusions

The recognition method proposed in this paper is put forward based on the original recognition theory, and can solve some problems of morphological changes caused by pressure. However, there are many changes in fine point lines. In order to give full play to the recognition value of fine point lines, the following two problems still need to be solved.

Firstly, if we can solve the problem of whether the fine point lines change or not, we will greatly improve the efficiency of recognition. Fine point lines are easy to change. If the material examined is inconsistent with the sample, the manual inspection will be interfered, and there will be no obvious significance of automatic identification. If the material examined is consistent with the sample, it will provide important information for manual identification, and will improve the recognition efficiency of the system. Therefore, to solve this problem is of great significance to the automatic recognition of fine point lines.

Secondly, the pressing conditions have a great influence on the image quality. In the process of pressing, we should try to reduce human interference. If the pressing pressure is too small, the fine point lines will not appear; if the pressing pressure is too big, the fine lines will be connected with normal lines, and it will difficult to extract them through the method proposed in this paper. These circumstances greatly increase the difficulty of recognition. Therefore, in the process of pressing, the pressure should be as close to the pressure of remaining samples as possible.

The identification method proposed in this paper is only a technical sample. To obtain the best scheme, repeated experiments and constant adjustment of parameters are required. In addition, factors such as matching time and space occupied should also be considered in the experiment. Due to limited time, no further work has been carried out to verify it. This paper focuses on the recognition of fine point lines. In the process of practical application, we should continue to explore the application of new technologies such as multi-feature recognition and multi-modal biometric recognition to give full play to the recognition value of fine point lines.

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