International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 4, May-June 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Model and Implementation of Large-Scale Fingerprint Image Retrieval

Bo Wang, Wenjing Ai, Xin Lin

School of Information, Beijing Wuzi University, Beijing, China

ABSTRACT

Since the 21st century, along with the continuous renewal of digital image acquisition equipment and popularization, the number of the fingerprint image data of explosive growth, one-to-one matching for fingerprint identification method seriously affect the efficiency of fingerprint database system identification, vlsi fingerprint database retrieval problem be there's an urgent need to solve a problem. Therefore, it is necessary to introduce the pre-screening technology, that is, image retrieval technology, design an efficient and accurate search algorithm to eliminate as much as possible in the large-scale database with the query fingerprint image does not have the "same" relationship of the image, reduce the fingerprint matching space. After such retrieval process, relatively few fingerprints in the database and query fingerprints have a high degree of similarity, and then the one-to-many comparison mode is adopted to compare and match one by one, which can effectively reduce the time used in the whole identification process. In view of this, the design of efficient and accurate search algorithm has become one of the focuses of large-scale fingerprint image retrieval.

KEYWORDS: *Fingerprint retrieval, detail point descriptors, feature similarity, best reference points, fingerprint matching*

How to cite this paper: Bo Wang | Wenjing Ai | Xin Lin "Model and Implementation of Large-Scale Fingerprint Image Retrieval" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-4, June 2022, pp.1242-1249, URL: www.ijtsrd.com/papers/ijtsrd50264.pdf

IJTSRD50264

1. INTRODUCTION

Since entering the 21st century, with the continuous updating and popularization of digital image acquisition equipment, the number of digital images has been increasing explosively. Almost all the application fields involving image information must face such a difficult problem: how to retrieve the required image from the massive image information. Fingerprint technology has been widely used in every field of people's life due to the advantages of uniqueness and invariance of fingerprint[1]. Fingerprint matching has been widely used in people's life, and its application fields will continue to expand. In the face of the gradually increasing scale of fingerprint database, if one-to-one matching is still adopted, the efficiency of the whole system of automatic fingerprint identification technology will be seriously affected [4]. As a result, the search mode of one-to-many comparison will lose its practical application value due to the large amount of data and long traverse time. Therefore, it is necessary to introduce the pre-screening technology, that is, image retrieval technology, and design an efficient and accurate search algorithm to eliminate as many images in the large-scale database as possible that do not have the "same" relationship with the query fingerprint image, so as to reduce the space of fingerprint matching[5,6]. After such retrieval process, relatively few fingerprints in the database and query fingerprints have a high degree of similarity, and then the one-to-many comparison mode is adopted to compare and match one by one, which can effectively reduce the time used in the whole identification process. In view of this, nowadays with the gradual expansion of fingerprint database scale, how to design efficient and accurate search algorithm is particularly important. Each fingerprint itself contains a large number of detail points. Due to various factors, even if the fingerprint collection is incomplete or a certain number of pseudo-detail points are extracted, the neighborhood of detail points can also form a topological structure, so feature matching using detail point information has high reliability[7]. By comparing various retrieval methods, this paper proposes a fingerprint retrieval algorithm based on

detail point descriptors. The constructed detail point descriptors are independent of each other and have little influence on each other, which overcomes the influence of false structure information between different detail points. Combined with the given data, it is considered that the detail-based descriptor algorithm is most suitable. By establishing the corresponding relationship between fingerprint features, the feature structure is established, and then the similarity between features is measured[8,9].

2. Basic assumptions and related definitions

2.1. The basic assumptions of the model

In order to facilitate the consideration of the problem, we made the following assumptions according to the conditions given in the question without affecting the accuracy of the model:

1. It is assumed that the data set obtained by using various methods is still reasonable and credible.
2. Assume that the number of pseudo detail points in the provided detail point data set is within the error range.

2.2. Symbolic description of the model

Table 2-1 Symbols description

Symbol	Meaning
P_0	Extract detail points
θ_0	Extract the direction field of the detail point
P_i	Auxiliary point
θ_i	The direction field corresponding to each auxiliary point
a_n 、 b_m	A detail in a fingerprint image
$G(i)$	Details of the point a_n 、 b_m Between descriptors i Angular deviation
S	Similarity
T_i	The threshold
L	Detail points describe sub-match points
$Q(\Delta x, \Delta y, \Delta\theta)$	Coarse match point set
$d(k)$	The error of other matching points in the coarse matching point set
C_m	Matching points of detail points under the best reference point
R	Number of endpoints in a matching point

3. Model construction

In this paper, the combination of detail point description method, fingerprint direction field and rough matching set method is used to effectively draw on the experience and professional knowledge of experts and make use of the objective information of data to distinguish fingerprint information, so as to avoid too subjective or too objective judgment[10] .

3.1. Detail point descriptors

Polygons composed of detail points are relatively reliable heuristic information, which can describe the geometric topological structure of detail nodes well. However, polygon structure has obvious defects. There is an exponential relationship between polygon count and detail count. If not restricted, the retrieval efficiency will be seriously affected. In this paper, the above phenomenon is called the contradiction between polygon recognition ability and the number of retrieved features, which is essentially a dimension trap. The detailed descriptor established in this paper can easily solve the above problems, and this method has the following advantages:

1. Constructed detail descriptors are independent of each other with little mutual influence and can well tolerate the influence of missing details and wrong details;
2. The detail descriptor uses a stable direction field around the detail and has good robustness to low quality fingerprint images;
3. The parameters in detail point description are invariant to translation and rotation;
4. Fingerprint matching was carried out using structures similar to detail descriptors, and good verification results were obtained, indicating that detail descriptors can accurately describe fingerprint characteristic information .

The construction of the detail point descriptor is shown in Figure 3-1. Where, the extracted detail point is assumed to be P_0, and the extracted direction field of the detail point is θ_0; Draw a circle with a radius of R and P_0 as the center of the circle, and evenly take out 3 auxiliary points on the circle, which are P_1、 P_2 and P_3 respectively; The direction field of the detail point P_0 and the focus of the circle is auxiliary point P_1, and the degree of the interval between the auxiliary points P_1、 P_2 and P_3 is 120°, and the direction fields corresponding to the three auxiliary points are θ_1、 θ_2 and θ_3 respectively. In order to improve the retrieval effect, if the auxiliary point is located in the non-fingerprint region, the corresponding detail point is considered invalid[11]. The size of the field radius of the detail point descriptor will affect the detail point comparison of the fingerprint image, and the optimal field radius value will be obtained through several experiments based on specific data sets below[12].

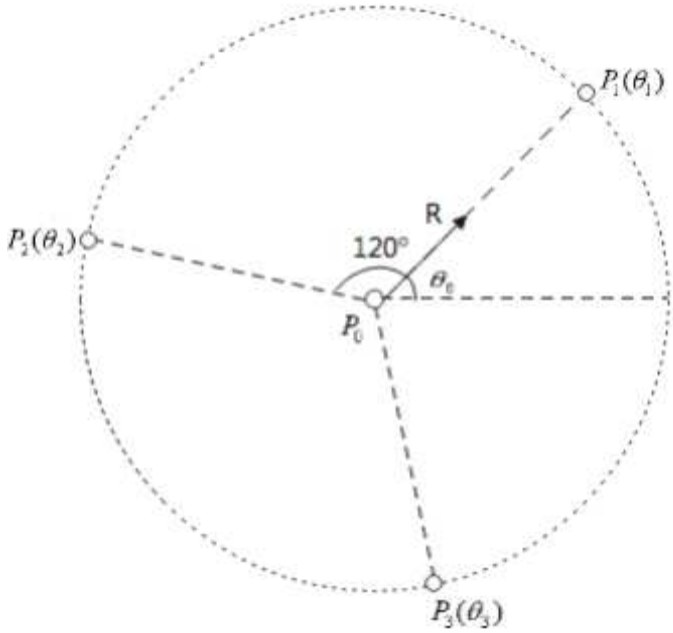

Figure 3-1 Detail point descriptors

3.2. Fingerprint direction field

The direction field of detail point descriptor is the auxiliary information of detail point descriptor, and its accuracy will directly affect the algorithm effect[13] .Refer to the literature and use the gradient operator to calculate the direction field of the region where the detail points are located. The specific steps are as follows：

1. The minutiae image of fingerprint is drawn according to the minutiae coordinates of fingerprint;
2. Divide the image into N*N fixed squares;
3. Sobel operator is used to calculate the gradients $\partial_x(i,j)$ and $\partial_y(i,j)$ of all detail points in each grid;
4. The gradient value of the detail point is used to calculate the direction of the direction block. The formula is as follows:

$$v_x = \sum_{u=i-N/2}^{i+N/2} \sum_{v=j-N/2}^{j+N/2} (\theta_x^2(u,v) - \theta_y^2(u,v))$$

$$v_y = \sum_{u=i-N/2}^{i+N/2} \sum_{v=j-N/2}^{j+N/2} (2 \times \partial_x(u,v) \times \partial_y(u,v)) \qquad (3.1)$$

$$\theta(i,j) = \frac{1}{2} arc\tan\left(\frac{v_y}{v_x}\right)$$

3.3. Rough matching

The retrieval algorithm in this paper mainly compares the local direction field information of two detail point descriptors, judges whether the two detail points match, and obtains the rough matching point set of fingerprint A and B. During the collection, finger fingerprints are randomly placed, and the collected fingerprint image will be translated and rotated[14]. Therefore, the minutiae used to describe the corresponding relative feature information can reduce the impact of translation and rotation. The specific steps of the algorithm are as follows:

Select any fine node a_n in fingerprint image A and traverse all detail points in fingerprint image B. If there is a fine node b_m in fingerprint image B, and the detail point is satisfied that the type of fine node a_n is the same and the position translation is within the range of $(\pm\Delta x_0, \pm\Delta y_0)$, go directly to step (3); However, if there is no detail a_n

corresponding to the fine node b_m after traversing all the detail points in the fingerprint image B, the detail points in the fingerprint image are discarded[15];

1. Next, continue to select the next fine node in fingerprint image A, and repeat step (1) until all the detail points in fingerprint image A are traversed;
2. Calculate the relative direction field angle difference between the two points inside the detail point descriptor constructed by the fine nodes a_n and b_m respectively, and the calculation formula is as follows:
$\Delta\theta_k = |\theta_i - \theta_j|(i, j = 0,1,2,3; i < j)$ (3.2)

Where, k is the number corresponding to the relative angle difference in the detail descriptor, and its range is $1 \le k \le 6$.

3. Calculate the angle difference of the relative direction field according to the formula in step (3), and calculate the deviation of the k-th angle between the fine node a_n, b_m descriptors, which is recorded as $G(k)$:
$G(k) = |\Delta\theta_k^{a_n} - \Delta\theta_k^{b_m}|(1 \le k \le 6)$ (3.3)

Where, $\Delta\theta_k^{a_n}$, $\Delta\theta_k^{b_m}$ respectively correspond to the angle difference of the k-th relative direction field of the fine node a_n、 b_m descriptor.

4. Check whether the two fingerprint fine nodes match:

A. If any $G(k)$ in formula (3.3) is greater than the threshold value T_1, it indicates that the two details do not match. Go back to step (1), otherwise go to the next step[16];

B. If two minutiae points match, calculate the similarity S, the formula is as follows:
$S = 1 - \frac{1}{6T_1}\sum_{k=1}^{6} G(k)$ (3.4)

C. If the similarity S is greater than the threshold T_2 it indicates that the two fine nodes are similar, and it is recorded in the array S_i;

(5) Repeat steps (1) ~ (5) until all the details of the input fingerprint are traversed to complete the matching. In the process of traversal matching, if the similarity between a fine node in fingerprint image A and multiple detail points in fingerprint image B is greater than T_2, then it is necessary to select the corresponding point with the largest similarity S in each array S_i as the matching point; Finally, record the point set $Q(\Delta x, \Delta y, \Delta\theta)$, the matching logarithm is L, and the deviation between each pair of fingerprint matching points is $(\Delta x_i, \Delta y_i, \Delta\theta_i)$.

4. Application and solution of the model

4.1. Data set

The data set selected in this experiment is the fingerprints of 500 people randomly selected from the fingerprint database, which are the same finger, the same finger out of order and the different finger data set respectively.

4.2. Predictive retrieval threshold

The experimental process is as follows:

A. Calculate the quality grade of all fingerprints in the training set based on MPNLI's fingerprint quality calculation formula, and then classify them according to the fingerprint grade;

B. The penetration hit ratio curves of fingerprint images of different quality levels were analyzed. Among them, the quality-grade probe fingerprint is retrieved by the quality-grade-based fingerprint retrieval method.The retrieval results are shown in Table 4-1. The quality-grade probe fingerprint is retrieved by the fingerprint retrieval method based on the results shown in the figure;

C. Assuming the retrieval threshold when the hit ratio is h=100%, the values of penetration, threshold Mp and M are obtained as shown in the table according to the method shown in the algorithm, where Tp is the threshold obtained in the penetration-hit ratio curve of the training set, and M is the threshold of the predicted retrieval system.

Table 4-1 Penetration rate and threshold of each quality grade when the hit ratio is 100%

Quality grade	8	7	6	5	4	3	2
Penetration rate	2.03	3.45	10.39	14	24	39.1	58
The threshold value Mp	148.57	128.38	93.29	65.39	45.29	22.69	9.34
The threshold value M	130.29	130.29	90.84	60.2	42.1	21.33	8.13

4.3. Solution of model

In this paper, it is assumed that there are d groups of fingerprints in the fingerprint database, the known database fingerprint matching the test fingerprint I is I_m and the detection score of the test fingerprint and the matching fingerprint is S_m that is, the search score when the test fingerprint I is successfully matched is S_m and the penetration rate of the test fingerprint I can be obtained assuming that the order of S_m in all scores is m. The formula is as follows:

$$P_m = \frac{m}{d} \times 100\% \quad (4.1)$$

The hit rate of a certain penetration rate P is as follows:

$$H = \frac{n_p}{M} \times 100\% \quad (4.2)$$

Where, M is the number of tested fingerprints, $n_p$is the number of tested fingerprints whose penetration rate is smaller than P.

An experimental database was established to verify the retrieval algorithm, with a total of 10800 fingerprint details. The neighborhood radius of detail point descriptor directly affects its recognition ability. In this paper, when the penetration rate is fixed at 10%, 15% and 20% respectively, the performance curves of neighborhood radius R and hit ratio are obtained, as shown in Figure 4-1. According to the distribution of the three curves, the neighborhood radius R at 25 ~ 33 fingerprint retrieval rate of rise is bigger, when combined with other penetration rate performance improvement at the same time, the algorithm in detail point descriptor in the best neighborhood radius R is 30, detail point descriptor identification ability, the strongest makes best fingerprint retrieval effect.

In this paper, the algorithm curves of hit ratio and penetration rate are obtained in the same database and the different database respectively. The results in the figure show that the algorithm in this paper has good results in the detection of the two databases .

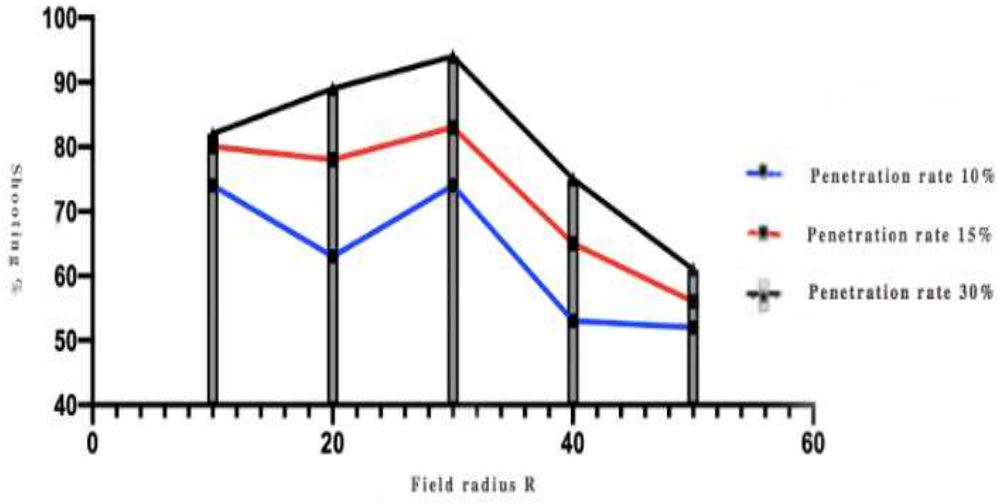

Figure 4-1 Curve of field radius and hit ratio

As shown in Table 4-2, when the hit ratio is 90% and 95%, the difference between the proposed algorithm in the two fingerprint databases is 0.25%-0.55% in the comparison between the three algorithms in the difference between the two fingerprint databases, and the change is the least among the three algorithms. It can be seen that the performance of fingerprint retrieval algorithm based on detail point descriptor proposed in this paper is better than that of traditional fingerprint retrieval algorithm, and the algorithm performance is the most stable.

Table 4-2 Curves of the different finger database

Algorithm	90		95	
	Different values	Refers to the order	Different values	Refers to the order
In this paper	8.3	7.5	20	17.4
Average cycle fingerprint classification	17.4	10.1	25.3	22.3
Singularity fingerprint retrieval	26.8	20.2	30.7	19.3

In order to verify the feasibility of the algorithm, a modular fingerprint database is used to simulate the algorithm's time and efficiency, and the average time of matching a fingerprint in the same number of fingerprint databases is calculated. As shown in Figure 4-2, this further proves that the fingerprint retrieval algorithm proposed in this paper needs a short time and can achieve a fast fingerprint retrieval process.

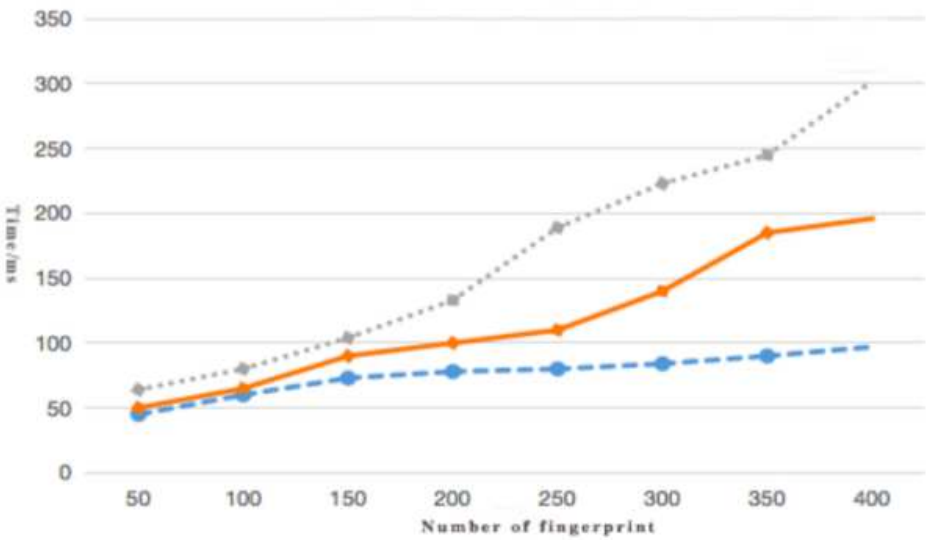

Figure 4-2 Fingerprint database and time curve

5. Summary

Experimental data are used to verify the fingerprint retrieval algorithm proposed above. The detail point descriptor algorithm reduces the influence of false detail points in the retrieval process, and determines the best reference points from rough matching points, so as to calculate fingerprint similarity. Through the analysis of experimental indexes, it is concluded that the fingerprint retrieval algorithm proposed in this paper has a good application effect. The results of this problem show that the proposed retrieval algorithm effectively solves some shortcomings of traditional methods, and has better performance and higher robustness compared with other retrieval algorithms, such as geometric feature retrieval algorithm between detail points.Fingerprint retrieval algorithm is to study how to establish a more efficient index and retrieval structure through the algorithm to extract fingerprint features, improve the speed of the entire retrieval system on the premise of ensuring accuracy, so as to improve the efficiency of the fingerprint retrieval system. Algorithm is the most critical factor to improve the efficiency of fingerprint retrieval system, but the breakthrough of algorithm is usually covered by long-term efforts and people's accumulation, so the research on fingerprint algorithm is concentrated in the field of practical application.

In the fingerprint retrieval system constructed by fingerprint index, each image is represented by a feature vector. In the stage of database construction, all database fingerprint images should be indexed according to feature vector method. When searching and browsing fingerprint images, the similarity between each fingerprint feature vector and each fingerprint feature vector in the database is searched (called similarity search). By comparison, a large number of database fingerprint images with poor similarity to browsing images are removed first. The sequence consists of candidate sequences of fingerprints with high similarity between the remaining fingerprints and the detection images, and then an accurate one-to-one comparison algorithm is used. In the candidate sequence, whether to check the images spliced with the detection images one by one, and finally complete the search process. It can also be said that fingerprint index is a retrieval method to explore the similarity between fingerprint and database fingerprint image in feature space.

In recent decades, the research of fingerprint recognition is mainly focused on fingerprint preprocessing, feature extraction and matching algorithm, but the search algorithm of large-scale database is seldom studied. In 1997, R.S.Germain et al. proposed a kind of base detail point triangle fingerprint index method. Although some fingerprint indexing methods were introduced later, more indexing algorithms emerged only a few years ago, and most of them have only been validated in small fingerprint databases. These fingerprint index methods can be roughly divided into the following categories: fingerprint index method based on global feature, fingerprint index method based on local texture feature, fingerprint index method based on detail point, fingerprint index method based on SIFT or SURF, fingerprint index method based on comparison score, etc.

Most fingerprint index methods based on global feature and local fringe feature adopt feature structure index which is related to the direction and frequency of fingerprint fringe. Fingerprint indexing methods based on SIFT or SURF usually use SIFT or SURF features used in the field of image recognition to index pattern images. The fingerprint index method based on comparison score firstly uses a set of fixed fingerprint images to form a reference image set, and then uses the matching results between database fingerprint images and each reference image to build an index with fixed length codes. The point-based fingerprint index method uses the features (such as triangles, rectangles, etc.) between each point to index. Among the above index methods, the fingerprint index method based on detail points has the following advantages:

- Fingerprint details have the advantages of stable and reliable extraction points. At present, most large-scale fingerprinting is based on the details of the left fingerprint (such as the automatic fingerprint identification system of domestic public security departments); Therefore, for large-scale fingerprint databases, we can better integrate detail-based technology into the index automatic fingerprint recognition system.
- The detail features have local stability and good robustness to search and match the damaged fingerprint.
- Detail feature is a natural fingerprint feature with obvious resolution. Starting from manual recognition, the study of detail vertices has a history of hundreds of years and is very mature in theory.
- More mature fingerprint pretreatment methods, robust fingerprint enhancement and fingerprint segmentation methods enable some low-quality fingerprint images to extract reliable details. Therefore, basic detail method has more technical accumulation in low quality fingerprint image processing ability.

It can be seen that compared with the traditional retrieval algorithm based on geometric features between detail points, the retrieval algorithm adopted in this paper not only has a significant improvement in system retrieval ability, but also has the best stability performance under different fingerprint databases.

Based on the above reasons, this paper chooses the basic research direction, detail-based fingerprint index and retrieval method, and builds the index structure and retrieval method of large-scale fingerprint database.

References

[1] Song Dehua, FENG Jufu. Minutiae based on bar code and the depth of the characteristics of convolution fingerprint retrieval method [J]. Journal of pattern recognition and artificial, 2018, 31 (02): 175-181. The DOI: 10.16451/j.carolcarrollnkiissn1003-6059.201802009.

[2] Ye Xueyi, Zou Rumeng, Ying Na, JI Bisheng, Wang Hepeng. Visual constraint fingerprint enhancement of the triangle subdivision algorithm [J]. Journal of electronic measurement and instrument, 2021, 35 (11): 194-205. The DOI: 10.13382/j.jemiB2103894.

[3] Jin Lijie, Huang Guigen, Li Pin, Wei Yao. Radiation source classification based on envelope fingerprint feature recognition technology [J]. Journal of modern radar, and 2020 (01): 28-31. DOI:10.16592/j.carolcarrollnki.1004-7859.2020.01.006.

[4] Liang X, Bishnu A, Asano T. A robust fingerprint indexing scheme using minutia neighborhood structure and low-order delaunay triangles [J]. IEEE Transactions on Information Forensics and Security, 2017, 2(4): 721-733.

[5] Zhao Qi, PENG Xiaoqi, Guo Xinxing, Wang Jiankang. Fingerprint retrieval based on singularity area direction field [J]. Microcomputer information, 2010, 26(02):172-174+177.

[6] Xu F. Identity recognition system based on sound and fingerprint feature fusion clustering [J]. Electronics, 2013 (15): 42. DOI:10.16589/j.carolcarrollnkicn11-3571/tn.2013.15.080.

[7] Tian Jie, He Yuliang, Chen Hong, Yang Xin. A fingerprint recognition algorithm based on similarity clustering method [J]. Science in China Series E: Information Science, 2005(02):186-199.

[8] Kim D, Park H, Park J, et al. Implementation of a Diskless Distributed Database System for Large-Scale Webtoon Image Fingerprint Data Retrieval [J]. The Journal of Korean Institute of Communications and Information Sciences, 2019, 44(1):137-147.

[9] Zheng R, Zhang C, He S, et al. A Novel Composite Framework for Large-Scale Fingerprint Database Indexing and Fast Retrieval. IEEE, 2011.

[10] Tan X, Bhanu B, Lin Y Q. Fingerprint identification: classification vs. indexing[C]// IEEE Conference on Advanced Video & Signal Based Surveillance. IEEE, 2003.

[11] Li Xiaohong, He Guiming, Jia Guoying. A Retrieval Method based on Large Fingerprint Database [J]. Computer Engineering and Applications, 2002, 38(19):3.

[12] LIU Na. Image threshold segmentation method based on particle swarm optimization and its application [D]. South-central University for Nationalities.

[13] LIANG Yao. Design and implementation of distributed mass fingerprint recognition system [D]. University of Electronic Science and Technology of China, 2016.

[14] Liu M, Jiang X, Kot A C. Fingerprint Retrieval by Complex Filter Responses[C]// International Conference on Pattern Recognition. IEEE Computer Society, 2006.

[15] Leung, K. C, C. H. Improvement of Fingerprint Retrieval by a Statistical Classifier [J]. Information Forensics and Security, IEEE Transactions on, 2011.

[16] Mukherjee R, Ross A, Li C, et al. Indexing Techniques for Fingerprint and Iris Databases[J]. Dissertations & Theses - Gradworks, 2007.