Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533

RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

A Recognition Method for Texture Target

[1]Ruimei Tan, [2*]QingE Wu

[1]College of Mathematics and Information Science, Zhengzhou University of Light Industry, Zhengzhou, 450002, China
[2]School of Electrical and Information Engineering, Zhengzhou University of Light Industry, Zhengzhou, 450002, China

Abstract: Currently, the algorithm on texture image is a key technology to target recognition. For effectively carrying out the texture image recognition, this paper proposes a hierarchical recognition method, compares it with other texture recognition methods, and studies the feature extraction technology of fingerprint as an example. This paper consists of several sections which include the introduction of other target recognition methods, feature analysis on texture image which fingerprint here is selected, the feature extraction method presented by two aspects, i.e., extraction of appearance feature and extraction of essential texture feature, hierarchical recognition method presented and some comparison results discussed with existing recognition methods, description of conclusions and some prospects in future research. The simulation results show that the presented recognition method has some advantages. In the feature analysis on fingerprint, this paper gives the location method of interest area. In terms of feature extraction, this paper uses the texture decomposition to the interest area of fingerprint, extracts the features of decomposition coefficient and its energy features of texture. In terms of matching recognition, based on the proposed texture segmentation algorithm and feature extraction method, this paper uses the hierarchical recognition method to carry out the matching and recognition to fingerprint. In the simulation, the presented recognition method is compared with several existing major fingerprinting methods. The comparison results show that the correct recognition rate of this method is averagely increased by 1.66%, and its recognition speed is improved by 0.018ms. It shows that this method has a higher accuracy and efficiency on recognition. These researches in this paper provide a new way of thinking for target recognition, which has an important theoretical references and practical significance.

Keywords: Image preprocessing; Feature extraction; Target recognition; hierarchical recognition

1. Introduction

In real life, there is the authentication management of fingerprint identity in the social health system and security system. As well as identity cards on fingerprint, securities transaction fingerprint management, examination fingerprint identification, temporary residence permits management in education system, fingerprint access control management, fingerprint identification in the field of electronic commerce, fingerprint identification of wage claim, confidential room, key security and protection unit, fingerprint identity authentication management of driver, fingerprint identity management to early childhood transfers, and so on. Therefore, the research on fingerprint recognition technique is of important theoretical and practical significance.

The literatures (Zhang, etc., 2013; Jiang, etc., 2012; Kızrak, etc., 2011; Nanni, etc., 2006) gave some fingerprint recognition methods, however, without deeper research to some tiny fingerprints. Some literatures (Moros, etc., 2013; Lin, etc, 2011; Caldwell, 2013; Wang, 2012) introduced the application of identity recognition based on the comprehensive features of fingerprint, and gave the experimental results. The literature (Moros, etc., 2013) utilized the laser-induced oscillation damaged spectroscopy method and the machine learning method to extract some characteristic points from a fingerprint image of express service personnel, and implemented the fingerprint recognition based on the location and direction of these points. A pattern fingerprint classification was proposed by using the optical method of sensor measuring and the fractal method based on biological measuring in (Lin, etc, 2011). Among algorithms of image segmentation (Xie, etc., 2013; Edward, etc., 2011; Zhou, etc., 2013; Yu, 2011; Long, etc., 2013), one of these algorithms was the Fuzzy C-Means clustering (Yu, 2011) that has some better features, which could fit the human cognition pattern, be described concisely and clearly, be easy to implement and so on. However, there were some disadvantages in this algorithm such as its performance depends on the initial clustering center, slow convergence, poor antinoise capability, and so on. From the research on traditional Markov Random Field (MRF) (Long, etc., 2013), the segmentation effect of MRF to micro texture was better, but the segmentation result to macro texture had many small areas or isolated islands. This paper (Inyang, etc., 2014) developed an intelligent hybrid system driven by Sugeno-Type Adaptive Neuro Fuzzy Inference System (ANFIS) for the classification, identification and extraction of oil spillage risk patterns. But, ANFIS recognition method was short of accurate classification and recognition to texture image. However, the average correct recognition rate of the hierarchical recognition method proposed in this paper is 97.95%, which is better than the ANFIS method.

The target recognition method studied in this paper is mainly composed of three parts, i.e., feature analysis on texture image that is fingerprint, the feature extraction method presented by two aspects, matching and recognition method and some comparison results discussed with existing recognition methods, description of conclusions and prospects. The feature analysis on fingerprint is to carry out firstly a preprocessing for the acquired texture image samples, which includes the image clear and delimitation of interest area. In the stage of feature extraction, this paper extracts the features of bifurcation and triangular points by using the segmentation analysis. At the same time, this paper carries out the fingerprint decomposition to the preprocessed image based on the texture coefficient transform, extracts the texture features of fingerprint, and constructs the characteristic vectors. In the stage of matching and recognition, this paper calculates the distance between the characteristic vector of identified texture and that of known texture about fingerprint, and evaluates the close degree of texture between two vectors. Finally, the comparison between the obtained degree of texture and an experimental threshold is given. According to the minimum distance, the recognition result can be obtained. The recognition system of texture target is shown in Figure 1.

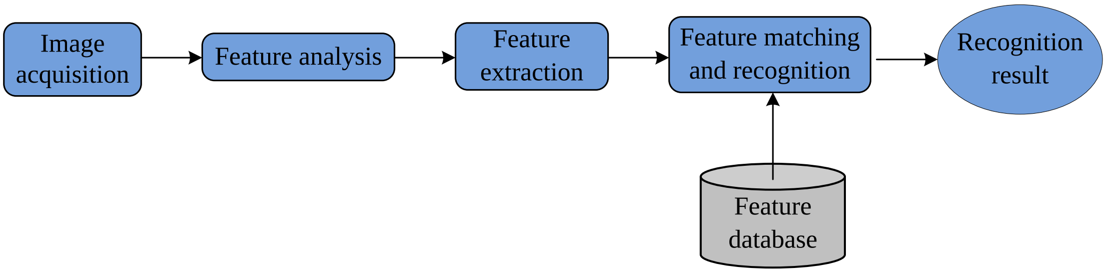


Figure 1. Texture target recognition system

2. Feature analysis on fingerprint

According to different fingerprint with different texture features, the fingerprint recognition technology is an authentication technology to determine the identity by comparing the local detailed features and the multiple global features between different fingerprint images. Relative to other recognition modes, the fingerprint recognition is more convenient and accurate.

The fingerprint referred to the grain generated by the jagged lines on the skin of the finger ends (Zhang, etc., 2013; Jiang, etc., 2012; Kızrak, etc., 2011). These lines existed to increase the friction of the surface of the skin, so as to make people be able to use the hand to grab the weights. Although the fingerprint was just a fraction of the human skin, it contained a wealth of information. The break point and intersection were varied, and the morphology of the grain varied with everyone, these lines of the skin in the pattern, i.e., the grain line of everyone was different each other, which was called a "feature" in information processing. Medicine had proved that the break point and intersection were varied, was a unique, remained unchanged in one’s lifetime, the grain of fingerprint of everyone in the pattern, and had a good uniqueness and stability. Based on this uniqueness and stability, it will be able to match a man with his fingerprint. Through his fingerprint was compared with previously saved fingerprints, his actual identity could be verified. Therefore, it had become one of the mainstreams for fingerprint recognition researches by utilizing the features of grain lines to carry out identification. In recent years, some researches (Caldwell, 2013) on fingerprint recognition had been attracted special attention, and some progress had been obtained, but further researches are to be made.

In comparison with most recognition methods, because the shape of fingerprint is stable and the acquirement of fingerprint image is convenient, the fingerprint recognition suffers fewer disturbances. Thus, a relatively fixed fingerprint image can be obtained no matter in what state, when and where. In a real extraction, either the one of those features of fingerprint may be extracted such as the one of bifurcation points and grain lines, or all features are extracted by high resolution acquisition equipment and fuse them together to construct a high precision recognition system for fingerprint.

The general fingerprint images acquired by ordinary camera mainly were performed by the processing algorithms discussed in the previous section. The resolution of these images is mostly low, so it can be not well adapt to the high-speed development requirements of science and technology. With the development of recognition technology for fingerprint, the fingerprint capturing device will be designed to be able to get a high resolution, high quality fingerprint image with clear details. In response to this trend, an extraction algorithm of fingerprint in interest area will be proposed to be suitable for high resolution images, and some geometrical characteristics of the papillary lines will be made full use of the on fingerprint, which will be discussed in detail as follows.

There are also widespread papillary ridges on a finger. Through a large number of observations, the papillary ridges on the fingers have certain regularity in some specific regions. To take the intersection point and the endpoint as an example, the feature point detection and extraction are discussed. The sketch map of intersection and endpoint are given in Figure 2. From their geometrical features attribute, they are the points that have high curvature, so Susan operator can perform well to detect and extract them, but Susan operator can’t distinguish one point is an intersection or an end-point on earth. Now, the further work is performed on the basis of Susan corner operator, i.e., an improved Susan corner operator is given as follows:

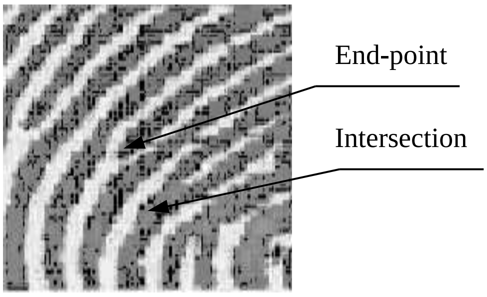


Figure 2. Detail features of fingerprint

Based on the Susan algorithm has detected out the corner points but is unable to distinguish the edge points, we take these points as the center of a circle O to do a group of concentric circle rings. We inspect a circle along clockwise direction on the circle rings in order to know the times of change of gray level. If the times of change of gray level are more than twice, then the above corner points or edge points are called the intersection. We carry out the algorithm in detail as follows:

If the gray value of the pixels is the same or similar as that of the center of a circle O in neighborhood of the point O, then we label the pixels as '1', and mark the other pixels as '0'. We inspect the pixel distribution things for any circle along the clockwise direction or anti-clockwise direction from the beginning of a certain point on the circle ring. We count the change times of gray value of pixels from '1' to '0' or from '0' to '1'. If the times of change of gray value are just right twice, the point O is called an end-point. However, the times of change of gray value are more than twice, the point O is called an intersection point.

3. Feature extraction to texture target

In section, the extraction method is presented through two aspects which consist of extraction of appearance feature and extraction of essential texture feature.

3.1 Extraction of appearance feature

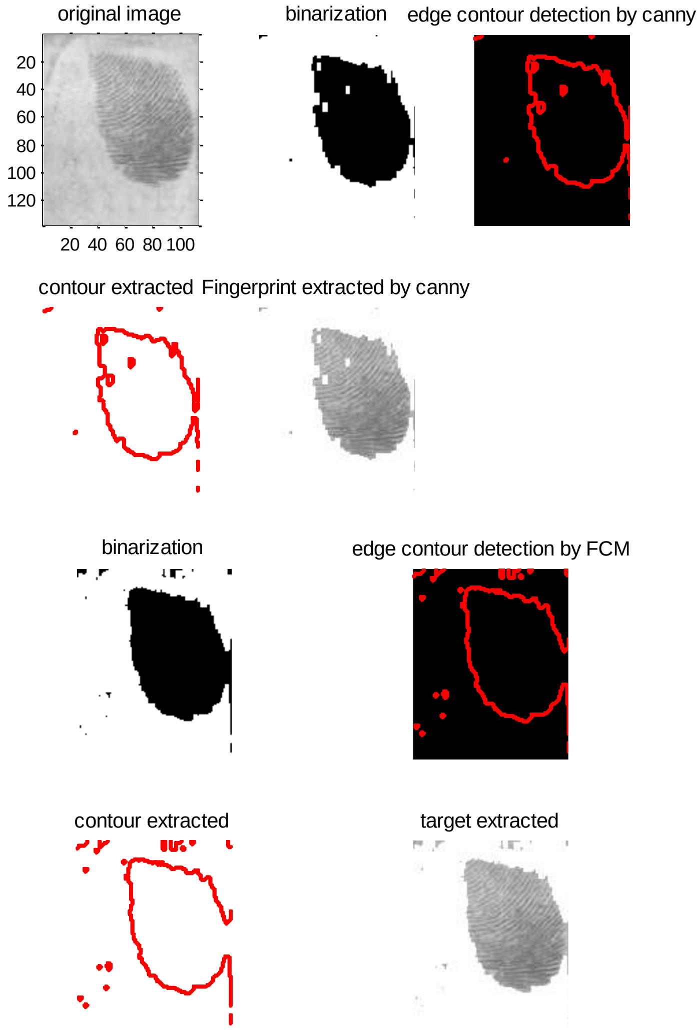
In a gathered fingerprint image, besides the noise in the data of fingerprint and background, the translation and rotation of fingerprint when is gathered can influence the quality of image. All these factors do not make against the extraction and matching of fingerprint features. Therefore, some preprocessing such as segmentation, calibration and normalization must be implemented before the features extraction of fingerprint is carried out.

3.1.1 Feature extraction of edge contour to texture image

The image border is the discontinuous reflection of local characteristics of an image, such as the mutation of gray level, colors and texture, which marks the end of a region and the beginning of another region. For the calculation simplicity, the first order derivative or the second derivative is usually used to check the border of an image. It can be easy to detect the discontinuity of gray level by taking advantage of the derivative method. The detection of border can be realized by the convolution based on the spatial differential operators. Some smoothness and binarization processing should be done before the extraction of border is implemented.

Assume the original fingerprint image is $f'(x,y)$, the smooth filtering to $f'(x,y)$ in a spatial domain can be carried out by using our previous work (Wu, etc., 2016), as well as a relative complete image of fingerprint edge can be obtained after filtering. Then the edge detection for the binarization image can be carried out in image width and image height directions by making use of gray-level mutation. The algorithm was also given in our previous works (Wu, etc., 2016).

Based on these previous works, the fitting curve that the position points x_k and y_k satisfy can be obtained. The edge line of fingerprint region can be obtained by carrying out borderline modeling of texture. This algorithm of texture segmentation is called the gray-level mutation algorithm. Figure 3 gives the extraction process of fingerprint edge based on the mutation algorithm, and shows the comparison between this mutation algorithm and existing extraction algorithms to fingerprint.



Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533
RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

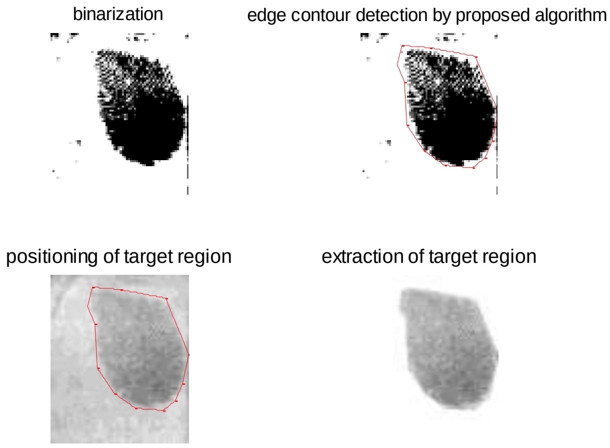


Figure 3. Extraction of fingerprint edge contour by several algorithms

From Figure 3 known, the marginal branches are many based on Canny and FCM algorithm to the contour extracted. However, the edge contour effect extracted by the proposed extraction algorithm is good, because the extracted edge is smooth and the contours can basically locate the target region.

3.1.2 Extraction of interest area

This section gives the method for extraction of interest area as follows:

In the coordinate system shown in Figure 4, how to divide up a fingerprint image and get the interest area that contains the abundant information and simplicity of operation, this paper gives a fast and convenient approach. That is to say, firstly, in the OP direction along x axis, searches a sharp growth value h_1 and a sharp reduction value h_2 in the gray-level mutation, then the left boundary l_1 and right boundary l_2 of interest area can be obtained. Secondly, in the OQ direction along y axis, searches a sharp growth value w_1 and a sharp reduction value w_2 in the gray-level mutation, then the upper boundary l_3 and lower boundary l_4 of interest area are obtained. Where, the sharp growth and sharp reduction in the gray-level have something to do with the amount of pixel of edge width and edge height of fingerprint, as well as the position of edge of fingerprint, i.e., the mutation case of gray-level is decided by the two factors.

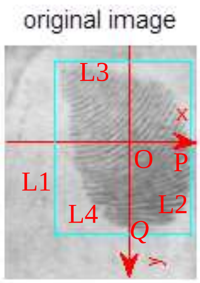


Figure 4. Construction of a coordinate system

The area of image falling within this region is extracted as the interest area, as shown in Figure 5. The interest area obtained in this way has eliminated the influence of noise, rotation, translation and so on. Experiment proved that the interest area extracted in this way is more beneficial to the subsequent feature extraction of fingerprint.

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533

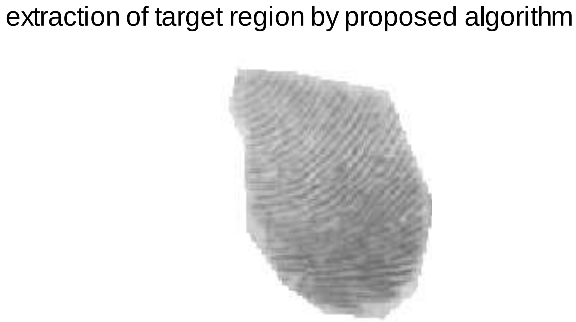


Figure 5. Positioning and extraction of target region

The area of interest area obtained by using this segmentation algorithm is bigger, which almost completely contains the grain ridges line of a fingerprint, its pattern, bifurcation point, end point, etc., as well as has a clearer papillary ridge. Therefore, the accuracy of the subsequent feature extraction and feature matching is improved. The difficulty of this algorithm is that it requires a high level acquisition device to obtain the high quality fingerprint images, and needs to build an image database that contains a large number of high quality fingerprints, so as to carry out some experiments.

In addition, the proposed extraction algorithm based on the gray-level mutation is compared with existing extraction algorithms for fingerprint, as shown in Figure 6. It can be seen from Figure 6, the extraction effect of the proposed extraction algorithm for fingerprints is better than that of other existing extraction algorithms, because it almost eliminates the background, reduces the noise and almost completely contains all the information on the fingerprint.

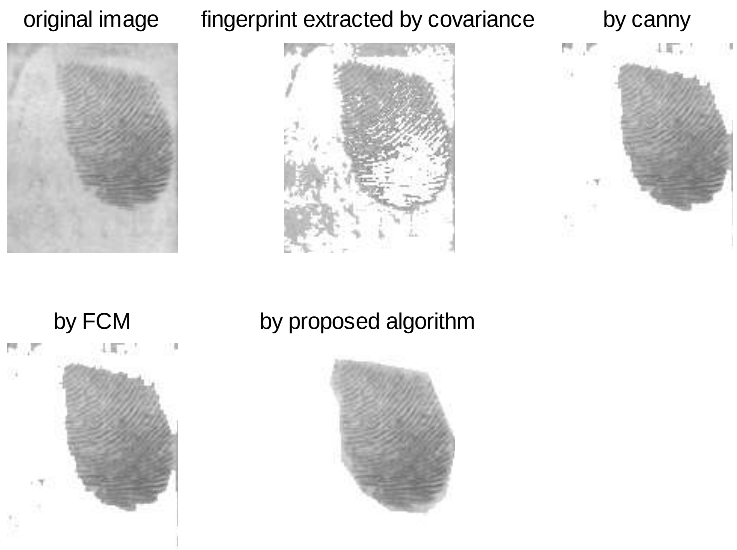


Figure 6. Comparison of fingerprint extraction

3.1.3 Extraction of characteristic points

(1) Adjustment of gray

Firstly, convert the original RGB image into gray image, and then adjust the range of gray image from [0.4, 0.6] to [0, 1], in order to obtain a clearer texture pattern of finger. Figure 7 shows the histogram of the image before and after adjustment. By the histogram, the grayscale range of distribution is uniform after the image transforms, therefore, an image with clearer texture information is obtained.

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533

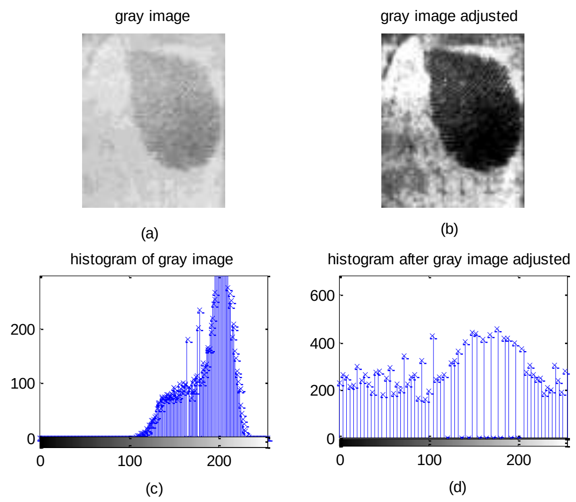


Figure 7. Adjustment of range of gray and histogram

In Figure 7, (a) is a gray image that the original RGB image is converted into. (b) is an image after the range of gray is adjusted. (c) is a histogram of gray image. (d) is a histogram after gray image is adjusted.

(2) Detection and extraction of characteristic points

The texture of fingerprint image is clear through processing by the above step, so it is easy to better implement the detection of characteristic points and tracking to them. According to the gray level jump algorithm given in the above, it can not only achieve the image edge detection and extraction, but also can detect and extraction a corner point, endpoint, bifurcation points, etc. The detection and extraction to corner points based on the gray level jump algorithm is shown in Figure 8.

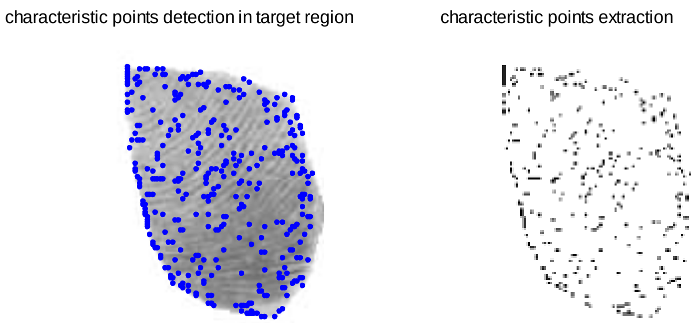


Figure 8. Detection and extraction to corner points based on the algorithm of gray level jump

The characteristic points are the endpoints, corner points, bifurcation points, etc., which the papillary ridges form on the fingerprint. The type of corner points detected by the gray level jump algorithm is various, so it requires filtering the detected corner points. Select a enough small radius r, and then take the corner points as the center of circle to draw a circle. We detect the times of change of gray level along this circle. If there are three sharp growth values or sharp reduction values of gray level jump at a certain point, the point is a characteristic point.

3.2 Extraction of essential texture features

The feature extraction of fingerprint is carried out by texture decomposition transform in here. Choose a function $\psi(\vec{t})$ to construct $\psi_{\vec{j},\vec{k}}(\vec{t}) = 2^{\vec{j}/2}\psi(2^{\vec{j}}\vec{t} - \vec{k})$, and make it do inner product with image $p(x,y)$, i.e. $\left\langle \psi_{\vec{j},\vec{k}}(\vec{t}), p(x,y) \right\rangle$, which can carry out some processing for a fingerprint image such as smoothing,

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533
RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

denoising, enhancing, compressing and so on. Where, $\vec{t}=(x,y)$, $\vec{j}=\left(j_1,j_2\right)$, $\vec{k}=\left(k_1,k_2\right)$.

Implement some preprocessing to texture image, for example, denoising processing method is as follows: The weighting function ω is used to adjust the image $p\left(x,y\right)$, and the adjusted algorithm is $G=\omega\otimes p$. Then, the image smoothing is carried out by the 3 layers decomposition of the texture feature, and the fuzziness of image is eliminated by using the threshold to sharpen it. By this preprocessing method for texture image, the quality of texture image is improved, and its clarity degree is also improved.

Now, carry out the extraction of essential features for texture image. A simple way is as follows: For a given threshold value δ, the texture features that all absolute of gray values are less than δ are recognized as noise and replaced by 0. But the texture features that are more than the threshold value δ are obtained by reducing, and the symbols of the obtained texture features are the symbols of the original texture features. This method means that the threshold removes minor extent noises or undesired features. The desired features can be obtained by feature inverse transform. The detailed algorithm was also introduced in our previous works (Wu, etc., 2015).

Another alternative way is usually to choose a two-dimension Gabor function as feature coefficient decomposition as follows:

$$g\left(x,y\right)=\frac{1}{2\pi\delta_x\delta_y}\cdot e^{-\frac{1}{2}\left[\left(\frac{x}{\delta_x}\right)^2+\left(\frac{y}{\delta_y}\right)^2\right]+j\left(ux+vy\right)} \tag{1}$$

Make it process the image $p\left(x,y\right)$, then the concrete algorithm is $W_{\vec{j},\vec{k}}=\left\langle\psi_{\vec{j},\vec{k}}(\vec{t}),p\left(x,y\right)\right\rangle$, which can carry out a decomposition and extraction of coefficient features of texture to image $p\left(x,y\right)$. For a region of texture with rich features, it shows that the texture is denser, the difference in amplitude is little, and the distribution of texture is regular as the decomposition levels increase. For a region with sparse texture, the texture takes on the form of jumping, sparse rendering as the decomposition levels increase.

From the decomposition calculation of coefficient of texture, the *i*th level texture feature of ripple is calculated by the *i*th level decomposition coefficient of texture, which shows the texture feature of a fingerprint image in the 2^{-i} scale, in different directions and different positions.

3.2.1 Feature extraction of coefficient of texture by decomposition

Assume texture image $g_j^n(t)\in U_j^n$, it can be expressed as $g_j^n(t)=\sum_l d_l^{j,n}\psi_n(2^j t-l)$. According to the calculation of texture decomposition, its decomposition coefficient is

$$\begin{cases} d_l^{j,2n}=\sum_k a_{k-2l}d_k^{j+1,n} \\ d_l^{j,2n+1}=\sum_k b_{k-2l}d_k^{j+1,n} \end{cases} \tag{2}$$

Where $a_n=\frac{1}{2}\overline{p}_n$ and $b_n=\frac{1}{2}\overline{q}_n$, $\overline{p}_n$ and $\overline{q}_n$ are the conjugation of p_n and q_n, respectively.

By the calculation of texture reconstruction, its reconstruction coefficient is

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533
RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

$$d_l^{j+1,n} = \sum_k [p_{l-2k} d_k^{j,2n} + q_{l-2k} d_k^{j,2n+1}] \tag{3}$$

Firstly, the 2-level decomposition to the preprocessed texture images is carried out by using texture decomposition function $\psi(t)$. The decomposition results based on a given texture basis are shown in Figure 9. The function $\psi_n(t)$ returns the tree structure of texture decomposition. It is an image user interface. The detailed images of the corresponding node are obtained by clicking at each node. Secondly, the texture decomposition coefficients of each node can be calculated by using the reconstruction coefficient function $d_l^{j+1,n}(t)$ at each decomposition layer, and the result is shown in Figure 10. Finally, all the coefficients are normalized to compose the characteristic vectors. Assume the characteristic vector of texture decomposition coefficient at the i th layer is V_i, then there is

$$V_i = \left(c_{i0}, c_{i1}, c_{i2}, \cdots, c_{2^{2i}-1}\right) \tag{4}$$

Where i denotes the number of layers of texture decomposition, c_j denotes the normalization coefficient values of texture decomposition at each layer.

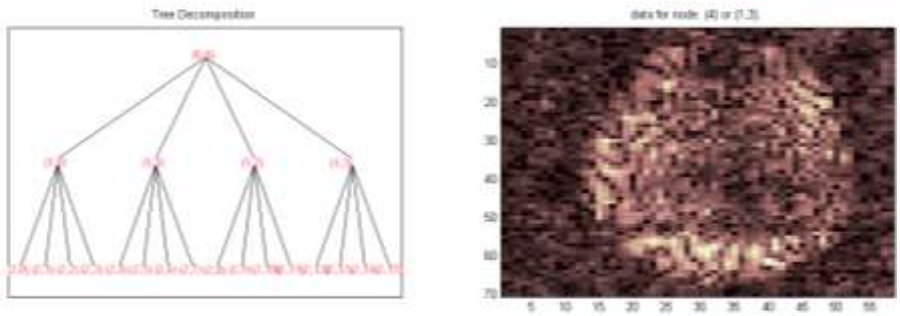


Figure 9. Nodes of texture decomposition and the detailed image at node (1, 3)

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533

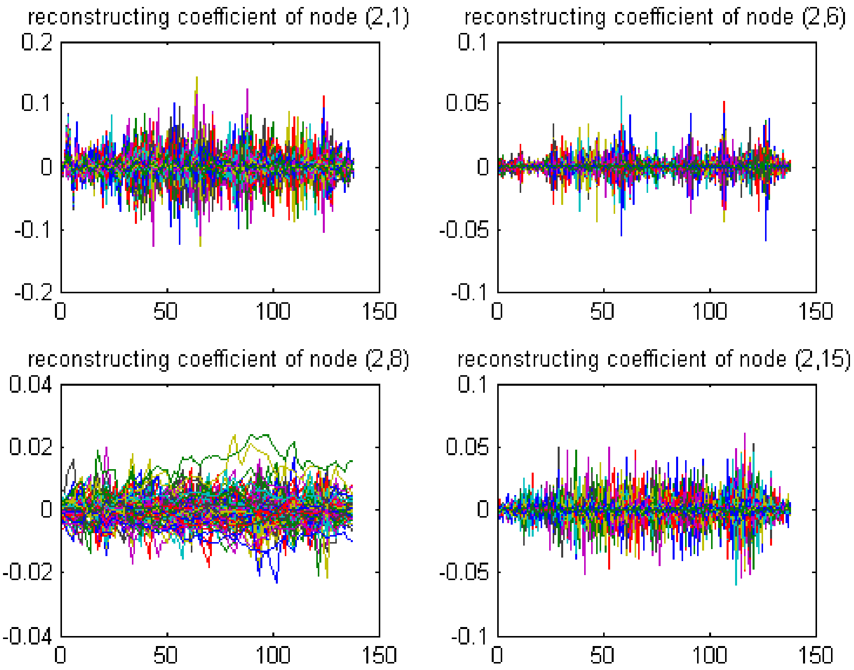


Figure 10. Reconstruction of texture features at different nodes

3.2.2 Feature extraction of energy of essential texture

The energy of texture features can be calculated by using the decomposition results of texture to image. According to the algorithm described in this paper, the energy of texture image decomposed by coefficient decomposition approach is defined as follows:

$$E_{(i,j)} = \sum_{x=1}^{n\times 2^{-i}} \sum_{y=1}^{m\times 2^{-i}} [H_{(i,j)}(x,y)]^2 \tag{5}$$

Where, $E_{(i,j)}$ is the energy of texture image at each node, and (i, j) denotes different nodes in a quad-tree of energy decomposition of texture. Under the 2-level energy decomposition of texture, there are $i \in \{0,1,2\}$ and $j \in \{0,1,2,\cdots,15\}$. $H_{(i,j)}(x,y)$ is the energy of texture of detailed image on each node. m and n are the height and width of the image, respectively. To extract the energy of texture of detailed image on each layer, the energy feature of texture decomposed by the coefficient can be established as follows:

$$E_i = \left(E_{(i,0)}, E_{(i,1)}, E_{(i,2)}, \cdots, E_{(i,2^{2i}-1)} \right) \tag{6}$$

Therefore, the E_i is called the energy feature of texture decomposition at the i th layer. It is normalized as follows:

$$E_j = \frac{E_{(i,j)}}{\sum_{x=1}^{n}\sum_{y=1}^{m}\left[H_{(0,0)}(x,y) \right]^2} \tag{7}$$

Where $j \in \{0,1,2,\cdots,2^{2i}-1\}$. The further simplification can be obtained:

$$E_i = \left(E_0, E_1, E_2, \cdots, E_{2^{2i}-1}\right) \tag{8}$$

The step of extraction method for essential texture features based on texture decomposition transform is outlined as follows:

(i) The appropriate function is chosen to carry out texture decomposition transform to a given image, and then the transform coefficient W of texture is obtained;

(ii) The threshold value δ of texture is calculated and the appropriate threshold method is chosen to choose or give up for the coefficients of texture. Thus, the new coefficients Wb of texture are obtained;

(iii) The obtained coefficients Wb of texture are carried out the inverse texture transform, i.e., the coefficients of texture are reconstructed, and then the essential features of texture are acquired.

4. Matching and recognition

4.1 Matching and recognition method

Based on the above method to feature extraction, different samples of fingerprint are trained and learnt, and the characteristic vectors of texture in different level can be acquired. Use these characteristic vectors as a standard template is stored in the system. We compare the characteristic vectors of unknown fingerprint image with the characteristic vectors of known classificatory fingerprint image that has been trained and stored in the retrieval system. Based on the minimum difference principle, if and only if the difference value between the characteristic vector of unknown fingerprint image and that of given i_0 th fingerprint image is minimal, we judge that the unknown fingerprint belongs to the i_0 th category. The feature matching of fingerprint is to judge whether two fingerprint images are from the same one fingerprint. If the matched result is positive, the system will output the information of the fingerprint. If the matched result is negative, the system continues to match with other standard templates. Therefore, the identification can be achieved.

The matching algorithm is given as follows:

If W_l is the known characteristic vector in the retrieval system, V is the characteristic vector to be identified. Where $l = 1,2,\cdots,Q$ and Q is the number of known characteristic vectors. The following distance is defined to estimate the difference between the texture characteristic vectors V and W_l of two wrinkles.

$$d_l = \|V - W_l\| = \sum_{i=1}^{n} |V_i - W_{li}| \tag{9}$$

Where, $|V_i - W_{li}| = \frac{1}{2^{2i}} \sum_{j=0}^{2^{2i}-1} \left|c_{ij}^{V_i} - c_{ij}^{W_{li}}\right|$ represents the difference between the characteristic vectors of

Journal of Engineering Technology
Volume 6, Issue 1, Jan. 2018, PP. 517-533
RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

coefficient for image, or $\left|V_i - W_{li}\right| = \frac{1}{2^{2i}}\sum_{j=0}^{2^{2i}-1}\left|E_{ij}^{V_i} - E_{ij}^{W_{li}}\right|$ is the difference between the characteristic vectors of texture of the image decomposed by coefficient. $c_{ij}^{V_i} \in V_i$, $c_{ij}^{W_{li}} \in W_{li}$, $E_{ij}^{V_i} \in E_i^{V_i}$, $E_{ij}^{W_{li}} \in E_i^{W_{li}}$, i is the number of layers of the coefficient to the image decomposition. The recognition principle is described as follows:

If $d_l < \varepsilon$, the identified fingerprint is considered to be belong to the l th category. Conversely, if $d_l > \varepsilon$,the fingerprint to be identified does not belong to the l th category. Where ε is a threshold value which is decided by experiment, as described in simulation section.

In the recognition process, it needs to search for all the samples in the database, so as to find the sample which it and the identified fingerprint image are from the same fingerprint, and then the fingerprint recognition is achieved. In order to improve the accuracy and efficiency of recognition, the hierarchical recognition method is introduced for searching. After preprocessing and feature extraction to each fingerprint image, the fingerprint image is determined by two kinds of characteristics. Firstly, the database is searched by the feature of decomposition coefficient of texture for the first time, and then the candidate set that consists of the fingerprint images of similar features of coefficient is obtained. Then, in the candidate set, the second search is carried out by using the texture feature of image decomposition achieved by coefficient, and then the final recognition results are obtained. In the recognition process, we use the feature of image decomposition coefficient to search for the first time, it is because its computational complexity is relatively small which increases the speed of recognition. To implement the search for the second time to the candidate set, because the number of samples in candidate set is less than that of in the database, similarly, the overall recognition efficiency is also improved. Figure 11 shows the flow chart of hierarchical recognition.

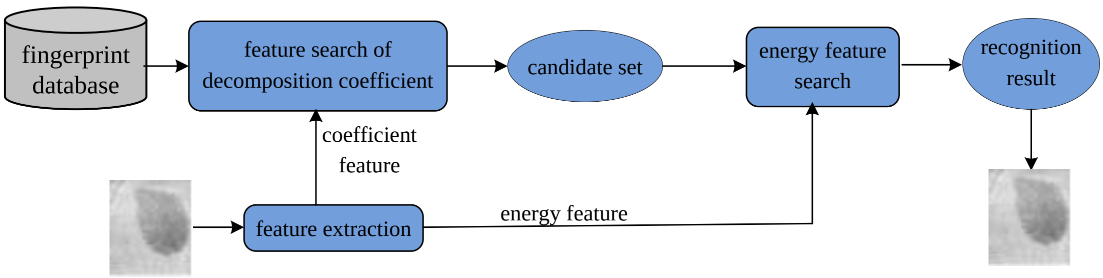


Figure 11. Flow chart of hierarchical recognition

4.2 Experiment and results analysis of hierarchical recognition

(1) Establish a standard template database

The main fingerprint used here is from the fingerprint database of a biometric identification research center, which is constructed by a certain image institute. The fingerprint image database used in experimental test and the sample database are established as follows:

(i) 150 different fingers are chosen from fingerprint Database, and 4 fingerprints are chosen from 6 fingerprint images of each fingerprint sampled in different time. Thus, 600 total fingerprint images are obtained.

(ii) A fingerprint is chosen randomly from 4 fingerprint images of each fingerprint, thus the first group are obtained, which is consist of 150 different images that are from 150 fingers and is taken as the learning samples database, and the other group is consist of the remaining 450 images and is taken as the test samples database.

(iii) The first group images are carried out an extraction of appearance feature and essential energy feature of texture by 3-level given coefficient decomposition. The 150 coefficient characteristic vectors C_i and 150 energy characteristic vectors E_i by 3-level coefficient decomposition to image are acquired, respectively, which are archived as training samples. Each characteristic set contains 150 characteristic vectors.

(2) Matching and recognition

The experimental basic steps of the matching and recognition for texture target are as follows:

P1. The second group images are used as the test samples to be identified. Firstly, a fingerprint image from the second group is chosen randomly, and is carried out the preprocessing and feature extraction with 3-level given coefficient decomposition. Then the obtained characteristic vectors are matched with those samples by using appearance features in fingerprint archive.

P2. Further, carry out matching and recognition to essential energy feature of texture. According to the hierarchical recognition process as shown in Figure 11, the coefficient characteristic vector to be identified is carried out the first matching with all characteristic vectors C_i of decomposition coefficient in the fingerprint archive. The candidate set is composed by the corresponding texture features which correspond to the matched similarity coefficient features.

P3. The characteristic vector of energy of texture to be identified is carried out the second matching with all energy characteristic vectors E_i of texture in the candidate set. The random selections and matching recognitions in 500 times are implemented based on the recognition principle, and the threshold value is chosen as follows:

Six fingerprint images that are from the same fingerprint are carried out the feature extraction of appearance and essential energy, and then six characteristic vectors are obtained. Compute the distance between any two characteristic vectors. For the obtained $C_2^6 \times 150$=2250 distances d_l, calculate their average values $\overline{d_l}$, and take it as the threshold value of distance matching. Where, $l = 1, 2, \cdots, 150$. The final recognition results are obtained.

P4. For each image in the test sample database, after 500 times recognition are done according to the step P1~P3, the times of the correct recognition and error recognition are recorded respectively, and the correct recognition rates are obtained by calculating.

(3) Results analysis

For each fingerprint image, 10 times repeating experiments are carried out from the step P1 to step P4 based on given coefficient basis function in simulation. The number of samples is different in each experiment. The proposed hierarchical recognition method compares with those currently better fingerprint recognition methods such as feature fusion and pattern entropy (Zhang, etc., 2013), MRF (Long, etc., 2013), ANFIS (Inyang, etc., 2014) and system method with eight-neighbor deviation (Nanni, etc., 2006). Based on the tests, as the number of samples increases, the correct recognition rate of a certain number of samples is obtained by statistics for each certain quantitative sample in the same time step, and further the average correct recognition rate of different quantitative samples is calculated within the sampling period. The average correct recognition rates of these methods are 97.95%, 96.94%, 96.36%, 95.58%, 94.63 % in simulation of 500 times, respectively. The simulation results are shown in Figure 12.

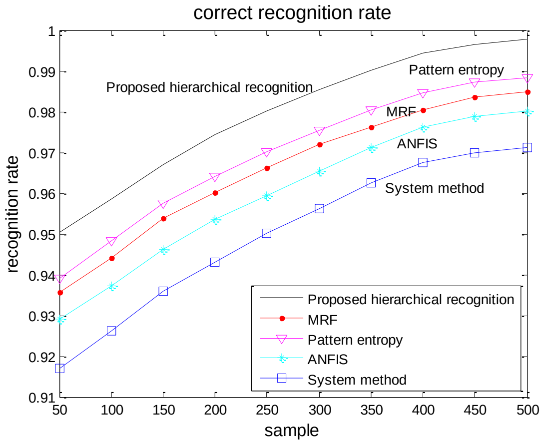


Figure 12. Comparison of correct recognition rate for the proposed and other methods

In order to evaluate the performance of each method, the presented recognition method is further compared with other recognition methods based on three factors which are the correct recognition rate, computing speed and communications traffic. The merits and demerits between the proposed method and existing methods are evaluated. The Table 1 gives the results of a comprehensive comparison.

Table 1: Comprehensive comparison of several recognition methods

Methods	Correct recognition rate	Computing speed	Communications traffic
Proposed method	0. 9795	0.189s	less
Pattern entropy	0. 9694	0.296s	much
MRF	0. 9636	0.258s	more
ANFIS	0. 9558	0.267s	more
System method	0. 9463	0.309s	much

From Figure 12 and Table 1 concluded, the average correct recognition rate of the proposed recognition method based on the feature extraction of appearance and essential energy is the highest and its processing speed is the fastest among all referred methods. In experiment, the average correct recognition rate increases constantly with the increasing recognition samples, and the curve of average correct recognition rate gradually levels off as the samples increase when the number of samples reaches a certain value.

On the basis of the simulation results, the recognition method based on feature extraction of appearance and essential energy not only has the faster processing speed, the lower memory capacity and communications traffic, but also has better recognition effect.

5. Conclusions and prospects

This paper analyzes the features of a fingerprint image such as wrinkles, pattern, papillary ridges of tiny lines, endpoint, intersection points, bifurcation points, and so on. Then, discusses feature analysis on texture image which fingerprint here is selected. A segmentation algorithm of interest area based on the edge contour of fingerprint and the feature extraction method is presented by two aspects which are the extraction of appearance feature and extraction of essential texture feature. The extraction method of appearance feature on interest area are given, as well as feature extraction of energy feature of texture based on coefficient decomposition to image. Moreover, this paper gives the matching and recognition method of fingerprint image, carries out the simulation test and also discusses some comparison results with existing recognition methods. Finally, the simulation results prove the feasibility and effectiveness of all proposed algorithms or methods in each stage.

How to combine other texture like the fingerprint and its feature to achieve a better and faster distinguishing effect is a question which need further study in the future.

Acknowledgments

This work is supported by National 973 Program (No. 613237) and Henan Province Outstanding Youth on Science and Technology Innovation (No. 164100510017), respectively.

References:

[1] Jie Zhang, Xiao-jun Jing, Na Chen, Jian-li Wang. (2013) Incomplete fingerprint recognition based on feature fusion and pattern entropy. The Journal of China Universities of Posts and Telecommunications, Vol. 20, n. 3, pp. 121-128.

[2] Xiubao Jiang, Xinge You, Yuan Yuan, Mingming Gong. (2012) A method using long digital straight segments for fingerprint recognition. Neurocomputing, Vol. 77, n. 1, pp. 28-35.

[3] Ayyüce M. Kızrak, Figen Özen. (2011) A new median filter based fingerprint recognition algorithm. Procedia Computer Science, Vol. 3,n.1, pp. 859-865.

[4] Loris Nanni, Alessandra Lumini. (2006) A novel method for fingerprint verification that approaches the problem as a two-class pattern recognition problem. Neurocomputing, Vol. 69, n. 7-9, pp. 846-849.

[5] J. Moros, J. Serrano, F.J. Gallego, J. Macías, J.J. Laserna. (2013) Recognition of explosives fingerprints on objects for courier services using machine learning methods and laser-induced breakdown spectroscopy. Talanta, Vol. 110, n.15, pp. 108-117.

[6] Chia-Hung Lin, Jian-Liung Chen, Chiung Yi Tseng. (2011) Optical sensor measurement and biometric-based fractal pattern classifier for fingerprint recognition. Expert Systems with Applications, Vol. 38, n. 5, pp. 5081-5089.

[7] Tracey Caldwell. (2013) Tabletop combines image display and fingerprint recognition. Biometric Technology Today, Vol. 2013, n. 8, pp. 12-13.

[8] Lingbo Wang, Xiaobing Wang, Lingyi Kong. (2012) Automatic authentication and distinction of Epimedium koreanum and Epimedium wushanense with HPLC fingerprint analysis assisted by pattern recognition techniques. Biochemical Systematics and Ecology, Vol. 40, n. 2, pp. 138-145.

[9] Xiaozhen Xie, Jitao Wu, Minggang Jing. (2013) Fast two-stage segmentation via non-local active contours in multiscale texture feature space. Pattern Recognition Letters, Vol. 34, n. 11, pp. 1230-1239.

[10] Edward H.S. Lo, Mark R. Pickering, Michael R. Frater, John F. Arnold. (2011) Image segmentation from scale and rotation invariant texture features from the double dyadic dual-tree complex wavelet transform. Image and Vision Computing, Vol. 29, n. 1, pp. 15-28.

[11] Hailing Zhou, Jianmin Zheng, Lei Wei. (2013) Texture aware image segmentation using graph cuts and active contours. Pattern Recognition, Vol. 46, n. 6, pp. 1719-1733.

[12] Jian Yu. (2011) Texture segmentation based on FCM algorithm combined with GLCM and space information. 2011 International Conference on Electric Information and Control Engineering, Wuhan, China, 15 Apr - 17 Apr 2011, pp. 4569 - 4572.
[13] Zhiling Long, Nicolas H. Younan. (2013) Multiscale texture segmentation via a contourlet contextual hidden Markov model. Digital Signal Processing, vol. 23, n. 3, pp. 859-869.
[14] Udoinyang Godwin Inyang, Oluwole Charles Akinyokun. (2014) A hybrid knowledge discovery system for oil spillage risks pattern classification. Journal of artificial intelligence research, vol. 3, n. 4, pp. 77-86.
[15] QingE Wu, Jifang Wang, Cunxiang Yang, Guangzhao Cui, Weidong Yang. (2016) Target recognition by texture segmentation algorithm. Expert Systems with Applications, vol. 46, n. 1, pp. 394-404.
[16] QingE Wu, Weidong Yang, Zhiwu Chen, Ping Zhang. (2015) Research of Semantic Understanding on Target Region of Interest for Fuzzy Image. Engineering Applications of Artificial Intelligence, vol. 37, n. 1, pp. 135-144.