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ALGORITHMS FOR FINGERPRINT CLASSIFICATION

Abstract. Currently, biometric methods of personality are becoming more and more relevant recognition technology. The advantage of biometric identification systems, in comparison with traditional approaches, lies in the fact that not an external object belonging to a person is identified, but the person himself. The most widespread technology of personal identification by fingerprints, which is based on the uniqueness for each person of the pattern of papillary patterns. In recent years, many algorithms and models have appeared to improve the accuracy of the recognition system. The modern algorithms (methods) for the classification of fingerprints are analyzed. Algorithms for the classification of fingerprint images by the types of fingerprints based on the Gabor filter, wavelet - Haar, Daubechies transforms and multilayer neural network are proposed. Numerical and results of the proposed experiments of algorithms are carried out. It is shown that the use of an algorithm based on the combined application of the Gabor filter, a five-level wavelet-Daubechies transform and a multilayer neural network makes it possible to effectively classify fingerprints.

Key words: Fingerprint classification, Gabor filter, wavelet transform, neural networks.

1. Introduction

Today biometric personality identification systems have been widely used in many areas of human life. For example, personal identification according to some characteristics is used in information security, forensic science, in the field of social services, and so on. One of the most common biometric technologies is fingerprint identification. It is this technology that has been widely used in various fields of activity. Since fingerprints do not change over the years and are unique for each person, this sign gives a high probability of correct identification of a person. Currently, computer technology is also involved in the process of personal identification by fingerprint. Each print has its own individual pattern, its own characteristics.

Fingerprints are one of the reliable biometric features successfully used for personal identification [1]. The advantages of a fingerprint for personal identification are:

• The uniqueness of fingerprints, different from each other and from other fingerprints of any other person. Even twins have different fingerprints.

• Unlike passwords, PIN codes cannot be lost or forgotten.

• Fingerprints do not change over time.

• Fingerprints have been used for many years for personal identification, therefore it is possible to test the developed algorithms using existing databases.

In each fingerprint, you can define two types of attributes - global and local. Global features are characteristics of a fingerprint that can be seen with the naked eye. Global features include image area, core, delta point, line counter, papillary pattern. Local signs, called minutiae, are small, unique dots for each fingerprint that are successfully used to identify individuals. A fingerprint may have the same global attributes, but local attributes are always unique.

However, the fingerprint image may be fuzzy, with indistinct lines and a lot of noise. Therefore, the image must go through a stage of preprocessing, during which noise and distortion are removed from the image, the readability of the fingerprint is increased.

The aim of this work is to create an algorithm for the classification of fingerprints by types of papillary patterns based on the combined application of the Gabor filter, wavelet transform and neural network. Solving this problem will speed up the search for fingerprints in large databases.

2. Global fingerprint signs

The image area is a fragment of a fingerprint in which all global features are located [1]. Fingerprints can be read and classified based on the image area information. Minutes that are used to identify a person may be outside the area of the image, so it is better to use information from a whole fingerprint when identifying a person.

The nucleus is the point that is located at the approximate center of the fingerprint and is used as a reference for reading and classification.

The «delta» point is the starting point where the separation or connection of the grooves of the papillary lines occurs, it can look like a very short groove, in the extreme case - a point. Line counter - the number of papillary lines on the image area, or between the core and the «delta» point.

Papillary patterns are divided into three types: arches (arcs), loops and curls [2]. Arches are rare and occupy 5 ... 10% of all fingerprints. Loops are found in most people (60 ... 65%). Curls appear much less often - 30% of all fingerprints.

3. Local signs of a fingerprint

The use of local features allows for detailed image analysis. To do this, the image is usually divided into rectangular areas, for each of which a vector of feature values is formed.

Examples of local features are statistical characteristics of the intensity distribution of image points.

Fingerprint lines are not straight. They are often broken, branched, reversed, and ripped. Points where lines end, branch, or change direction are called minutia points. These minus points provide unique information about the fingerprint for identification purposes.

Practice shows that fingerprints of different people can have the same global features, but it is impossible to have the same local features, i. e. points of mination. Therefore, the process of personal identification usually consists of two stages. The first step is globally categorizing fingerprints, using databases to classify them. The second step is to recognize the fingerprint based on the comparison of the structure and the coincidence rate of the minutia points.

4. Gabor filter

Gabor filter is a linear filter, the impulse transient response of which is represented as the product of a Gaussian function by a harmonic function [3]:

$$g(x,y) = \text{Gauss}\,(x',y')\cos(\tfrac{2\pi x'}{\lambda}), \quad (1)$$

$$\text{Gauss}(x',y') = e^{-\left(\frac{x'}{2\pi\sigma_x^2}+\frac{\gamma^2 y'^2}{2\pi\sigma_y^2}\right)}, \quad (2)$$

$$x' = x\cos\theta + y\sin\theta, \quad (3)$$

$$y' = -x\cos\theta + y\cos\theta, \quad (4)$$

where λ is the wavelength; ϕ – phase; the angle θ indicates the orientation of the normal to the parallel stripes of the Gabor function; γ is the compression ratio. Changing the orientation of θ makes it possible to change the direction of edge detection.

Fingerprint lines can be multidirectional, so it is necessary to find the orientation of the lines within each processed area of the image. This result can be achieved by applying different orientations of the Gabor filter to the image. In this case, by changing the angle of rotation θ, it is possible to change the direction in which the edges are to be detected. Therefore, the Gabor filter function will be a function of three variables – h (x, y, θ).

To find the orientation angle of the segment line, that is, the angle θ, it is necessary to construct a field of image directions, which is constructed using the point coordinates function, which describes the angle of the tangent to the line of the image intensity level. In this case, the field angle sets the direction, which is perpendicular to the vector of the image gradient, and the gradient, in turn, corresponds to the color changes from white to black.

If I (x, y) is the brightness of the light in the image, then the direction field φ (x, y) is given by the following equation:

$$\mathrm{tg}\varphi(x, y) = -(\partial I(x, y)/\ \partial x)/(\partial I(x, y)/\ \partial y), \tag{5}$$

where the angle φ (x, y) specifies the direction that is perpendicular to the gradient vector.

Next, filter matrices are calculated that correspond to all possible directions of lines in the range from 0 to 255. After that, a two-dimensional convolution with the Gabor filter kernel at the point (x, y) is performed on the image. In this case, the Gabor core corresponds to a given local angle of the line direction.

In image processing, the Gabor filter is commonly used for edge extraction, object outline detection, texture feature extraction, fingerprint image area extraction, local direction extraction, and other purposes [4, 5]. In this work, different orientations of the Gabor filter are used to improve the image of the fingerprint.

5. Wavelet transform

The main challenge in each type of image processing is to find an efficient representation that allows it to be displayed in a compact form. In modern theory and practice of signals in spectral analysis, signals of a special type are used - wavelets. The works [6, 7] present the decomposition of the image and the extraction of its features for the classification of aircraft images based on the application of the Haar wavelet transform and a multilayer neural network. In this paper, the Haar and Daubechies wavelet transforms are used to extract features of a fingerprint image.

In addition, according to the research results presented in the review [9], the choice of a particular wavelet basis has an insignificant effect on the texture analysis of images. Therefore, when choosing a wavelet basis in this case, the main criterion is the time and complexity of the transformation.

Wavelet analysis methods do not require splitting the image into small blocks, since the required localization properties are incorporated into the wavelet system [10].

6. Fingerprint classification method

In this paper, a method is proposed for classifying fingerprint images by types of papillary patterns based on the use of the Gabor filter, wavelet transform and a neural network. The functional diagram of the proposed method is shown in figure 1.

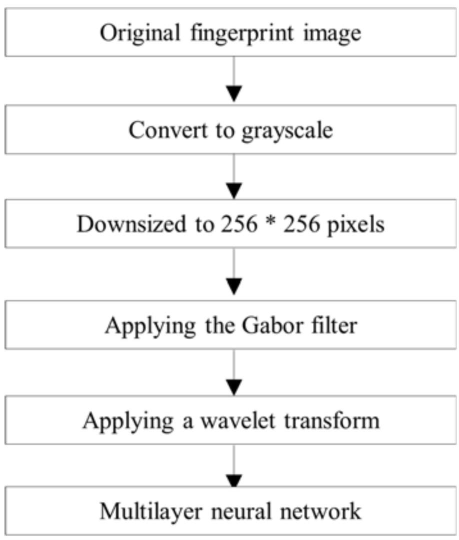

Figure 1 - Functional diagram of the proposed method of classification of fingerprints

The proposed method uses the Haar and Daubechies wavelet transforms to extract features of the fingerprint image. To evaluate the efficiency of feature extraction, 5th and 6th level wavelet transforms are used. A neural network with 192 inputs for the 5th level wavelet transform was created. The number of hidden neurons for this network varies from 200 to 250. For the 6th level wavelet transform, a neural network with 48 inputs was created, for which the number of hidden neurons varies from 80 to 120. Both networks have 7 outputs in accordance with the number of categories fingerprint classification.

7. Experiments

To test the algorithms, a part of the FVC2006 fingerprint database [8] is used, containing 9 images of each category for training (total 9 × 7 = 63 images), and 14 images of each category for testing (total

14 × 7 = 98 images). The results of comparing the efficiency of feature extraction are shown in Figure 2 and 3. Analysis of the above results shows that the algorithm using the Daubechies wavelet transform gives better results than the algorithm based on the Haar wavelet.

We also compared the performance of the algorithm using the Gabor filter with the algorithm without using this filter, Figure 4 and 5. The above results show that the algorithm using the Gabor filter performs better than the algorithm without this filter.

8. Conclusions

1. Proposed and described algorithms for classification of fingerprint images by types of papillary patterns, based on the use of the Gabor filter, the Haar wavelet transform, Daubechies and a multilayer neural network.

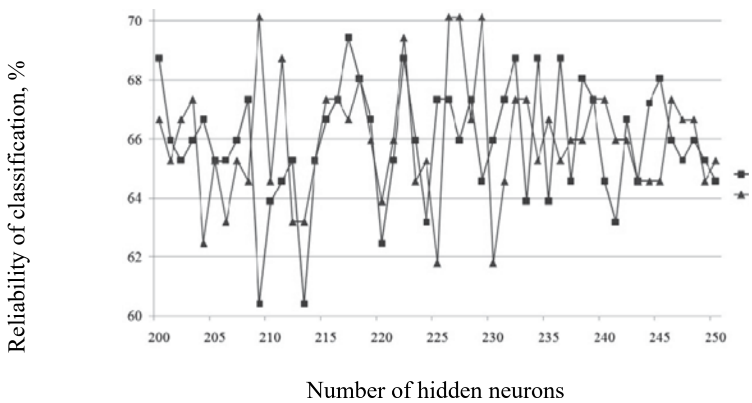

Figure 2 - The result of comparing the efficiency of the algorithm based on the application of a five-level wavelet transform: -Daubechie; - Haara

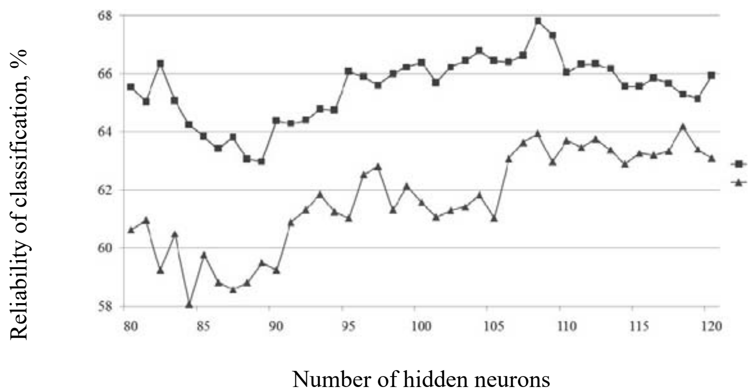

Figure 3 - The result of comparing the effectiveness of the algorithm based on the application of the six-level wavelet transform: - Daubechie; - Haara

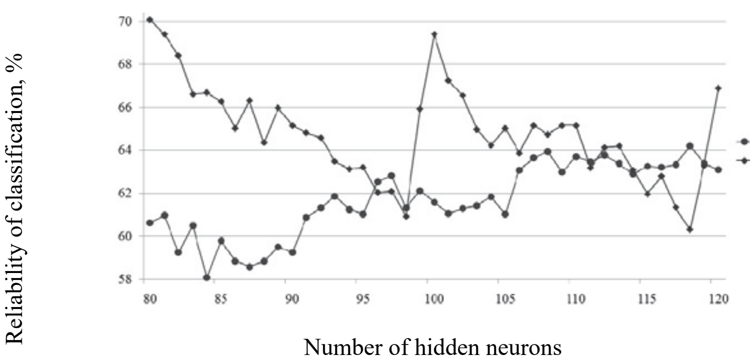

Figure 4 - The result of comparing the efficiency of the algorithm based on the application of the six-level Haar wavelet transform and: - with the Gabor filter; - without Gabor filter

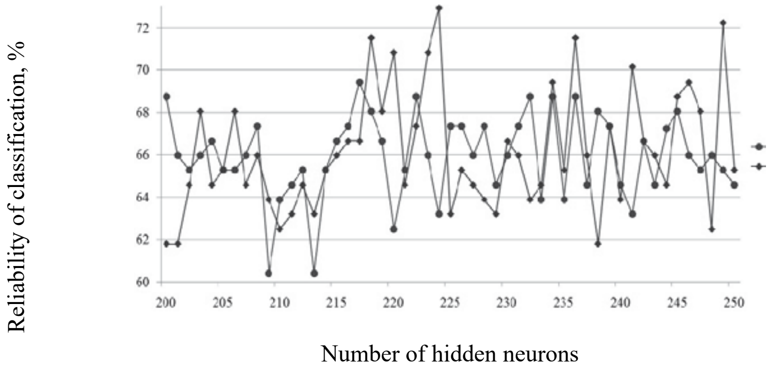

Figure 5 - The result of comparing the efficiency of the algorithm based on the application of the five-level Daubechies wavelet transform and: - with the Gabor filter; - without Gabor filter

2. Based on the analysis of the results of numerical experiments, it has been established that the algorithm based on the combined application of the Gabor filter, the five-level Daubechies wavelet transform and the multilayer neural network has the best reliability of classification of fingerprints.

Applying the Gabor filter on the fingerprint image sharpens lines, detects edges, and removes noise and distortion. However, the disadvantage of this method is the high computational complexity of the algorithm.

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САУСАҚ ІЗІ БОЙЫНША КЛАССИФИКАЦИЯЛАУҒА АРНАЛҒАН АЛГОРИТМДЕР

Аннотация. Қазіргі уақытта жеке тұлғаны танудың биометриялық әдістері тану технологияларына айналуда. Биометриялық сәйкестендіру жүйелерінің дәстүрлі тәсілдерге қарағанда артықшылығы, адамға тиесілі сыртқы объект емес, адамның өзі анықталады. Саусақ іздері арқылы жеке тұлғаны сәйкестендірудің ең көп таралған технологиясы, ол әр адам үшін папиллярлық өрнектің бірегейлігіне негізделген. Соңғы жылдары тану жүйесінің дәлдігін жақсарту үшін көптеген алгоритмдер мен модельдер пайда болды. Саусақ іздерін жіктеудің заманауи алгоритмдері (әдістері) талданады. Габор сүзгісі, толқындық Хаар, Добеши түрлендірулері және көп қабатты нейрондық желі негізінде саусақ іздерінің түрлері бойынша саусақ іздерінің суреттерін жіктеу алгоритмдері ұсынылған. Ұсынылған алгоритмдерге сандық және эксперименттік зерттеулер жүргізілді. Габор сүзгісін, бес деңгейлі толқындық түрлендіруді және көп қабатты нейрондық желіні бірлесіп қолдануға негізделген алгоритмді қолдану, саусақ іздерін тиімді жіктеуге мүмкіндік беретіні көрсетілген.

Түйін сөздер: саусақ ізінің жіктелуі, Габор сүзгісі, вейлетт түрлендіру, нейрондық желілер.

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АЛГОРИТМЫ КЛАССИФИКАЦИИ ОТПЕЧАТКОВ ПАЛЬЦА

Аннотация. В настоящее время биометрические методы распознавания личности становятся все более актуальными технологиями распознавания. Преимущество биометрических систем идентификации, по сравнению с традиционными подходами, заключается в том, что идентифицируется не внешний объект, принадлежащий человеку, а сам человек. Наиболее распространена технология идентификации личности по отпечаткам пальцев, которая основана на уникальности для каждого человека рисунка папиллярных узоров. В последние годы появилось много алгоритмов и моделей для повышения точности системы распознавания. Проанализированы современные алгоритмы (методы) классификации отпечатков пальцев. Предложены алгоритмы классификации изображений отпечатков пальцев по типам отпечатков пальцев на основе фильтра Габора, вейвлет - Хаара, преобразований Добеши и многослойной нейронной сети. Проведены численные и экспериментальные исследования предложенных алгоритмов. Показано, что использование алгоритма, основанного на совместном применении фильтра Габора, пятиуровневого вейвлет-преобразования Добеши и многослойной нейронной сети, позволяет эффективно классифицировать отпечатки пальцев.

Ключевые слова: классификация отпечатков пальцев, фильтр Габора, вейвлет-преобразование, нейронные сети.

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