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DEVELOPMENT OF BIOMETRIC IDENTIFICATION METHODS BASED ON NEW FILTRATION METHODS

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A new method of filtering biometric images based on Ateb-Gabor has been developed. The method is based on the well-known Gabor filter and allows you to rearrange the image with sharper contours. Therefore, this method is applicable to biometric images, where the creation of clear contours is particularly relevant. When Gabor filtering, the image is reconstructed by multiplying the harmonic function by the Gaussian function. Ateb functions are a generalization of elementary trigonometry, and, accordingly, have greater functionality. Ateb-Gabor filtering allows you to change the intensity of the whole image, as well as the intensity in certain ranges, and thus make certain areas of the image more contrasting. Ateb functions vary from two rational parameters, which, in turn, allows you to more flexibly manage filtering.

Keywords: filtering, Ateb-Gabor filtering, biometric images.

1. INTRODUCTION

The world is developing in the direction of greater informatization of both individual sectors of the economy and society as a whole. The problem of information security [1] is especially acute in connection with the rapid introduction of computer technology in the field of banking, insurance, medicine. The need to address the protection of information is also due to the sharp rise in computer crime, the result of which leads to significant material losses, whether it is a virus attack or fraud in e-commerce [2].

2. RECOGNITION OF BIOMETRIC DATA

When scanning biometric data, noise may be present in the image, which distorts the recognition results. Random noise is manifested in the form of chaotic granularities or foreign aliens in the image. The most noticeable such noise in dark areas of images, because the ratio of “signal/noise” on them will be much less than in light areas [3]. Any obtained image has a number of disadvantages: insufficient sharpness of images, blurred images or some details. Depending on the types of distortion developed different methods of image filtering, which are used in specific situations, and provide different quality recovery. The use of the filter in another situation depends on the type of noise. The most common impulse noise. In the influence of impulse interference on the image there are white or black interference, which are chaotically scattered throughout the image. Noise at the same time can be located not on all image, and obstacles look isolated isolated contrasting points. Today, a large number of methods for removing noise. Each separate method is used to eliminate a certain type of noise.

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The complexity of finding accurate solutions gives rise to different variants of approximate methods.

One of the known filtration methods is the Gabor filter [4]. It is used for linear filtering and improves the quality of the converted image. Additionally, operations of symmetry, antisymmetry and wavelet transform can be used to reduce the number of required multiplication and addition operations [5].

However, on a raw image due to noise, the print lines may be distorted, creating recognition errors. In addition, identification should be quick and take minutes. To do this, the image is enhanced by applying filtering. This reduces the noise of the image.

3. FINGERPRINT RECOGNITION TECHNOLOGY

Many targeted filtering techniques have been proposed to improve image prints, the most common of which was the use of a uniform symmetrical Gabor filter.

The generally accepted method of improving the quality of fingerprint images is as follows: starting with normalization, which aims to determine the average value and variance of the input image, which is then used to assess the local orientation in order to obtain orientation. Use of local frequency estimation, which aims to align the results of the local orientation estimation. An area mask is then evaluated, which is derived from the classification of each block in the normalized fingerprint image into blocks that can be corrected or cannot be restored. This step is intended to determine whether there is a value in the executed area that is less than or greater than the threshold. This step determines the input image to go to the next step or even rejected. If the area value is greater, then the stage where the filtering is performed is entered. This step aims to determine the value so that it can be filtered or not, which will subsequently affect the noise filtering. But this method requires another step, which is to increase the level of accuracy in the area of the mask.

Many improvements have been proposed to increase the reliability of recognition, but the most effective is a method that consists of several stages [4]:

1) segmentation;
2) normalization;
2) assessment of local orientation;
3) local assessment;
4) estimation of the frequency of hills;
5) using the Gabor filter;
6) binarization;
7) thinning.

The fingerprint image is divided into blocks of wxw (usually 8 × 8 or 16 × 16) pixels, which do not overlap, for which the local orientation and local spine frequency are calculated.

3.1. Segmentation

The first step in the fingerprint enhancement algorithm is image segmentation. Segmentation is the process of separating foreground areas in an image from background areas. The foreground areas correspond to a clear fingerprint area containing ridges and valleys, which is the area of interest. The background corresponds to areas outside the fingerprint area that do not contain any valid fingerprint information. When part extraction algorithms are applied to background areas of an image, it results in the extraction of noisy and erroneous details (Fig.1). Thus, segmentation is used to discard these background areas, which facilitates the reliable removal of small details.

Fig. 1. Fingerprint image taken with a sensor

In the fingerprint image, the background areas usually have a very low gray dispersion value, while the foreground areas have a very large dispersion. Therefore, a method based on the variance deviation threshold can be used to perform segmentation. First, the image is divided into blocks and the gray difference is calculated for each block in the image. If the variance is less than the global threshold, the background area is assigned to the block; otherwise it is intended to be part of the foreground. The gray level variance for a block of size W is defined as:

$$V\ (k) = \frac{1}{W^2}\sum_{i=0}^{W-1}\sum_{j=0}^{W-1}(I(i,j) - M(k))^2 \quad (1)$$

where $V(k)$ is the variance for block k, $I(i, j)$ is the value of the gray level in the pixel (i, j), and $M(k)$ is the average value of the gray level for block k.

3.2.Calculation of local orientation

The orientation field of the fingerprint image determines the local orientation of the ridges contained in the fingerprint (see Fig. 2). . Input images taken from the NIST database 24. Orientation is a key step in the improvement process, as the next step in Gabor filtering is based on local orientation to effectively improve the fingerprint image [6]. The least mean square estimation method is used to calculate the orientation image.

Fig.2. Input images taken from the NIST database 24

The local orientation can be calculated from local gradients using the arctangent function. This is very time consuming in embedded systems without a dedicated floating point unit. However, if Gabor cores with a fixed orientation are used for filtering, there is no need to calculate the exact orientation.

3.3. Normalization

The normalization process is performed for a uniform value of the intensity of the fingerprint image, adjusting the coverage of the gray level so that it is within the expected value. The process of normalization does not change the clarity of the ridge and valley structures. The main purpose of normalization is to reduce the difference between the values of gray on the ridges and valleys. When normalizing, the gray level values are in a certain range, sufficient to increase the contrast and brightness of the image, which will facilitate the next processing steps [7].

Images such as dim, color-balanced, or too bright images will be generated as a histogram. A method often used to process histograms is adaptive histogram alignment. This method produces a uniform histogram and is distributed in such a way that it is often called the term of histogram alignment.

After the process of normalization, the image has a good contrast, ie the image, which has an intensity distribution over the entire area.

Therefore, image normalization is required to increase the contrast between the ridge and the valley in the fingerprint images, where the normalization process will help the process of improving the fingerprint images.

3.4. Filtration

When filtering images, try to increase the sharpness. There are a large number of filters that allow you to zoom in on images with clear boundaries. In addition, there is noise when digitizing images. One of the most common types of filtration is the Gabor filter. It allows you to restore the image with the selection of contours at a certain frequency. Its nucleus looks like elements of the Fourier basis, which is multiplied by Gaussian. The widespread use of Gabor filters for filtering is due to the fact that it gives a strong reaction at those points in the image where there is a component with local features of frequency in space and orientation.

The availability of a fast Fourier transform algorithm for computer systems allows you to transfer image processing from manipulating the numerical values of the brightness of individual pixels to the processing of the signal obtained after the fast Fourier transform over the image. The ability to represent the image as a Fourier image makes it possible to apply filters used in signal processing. The study of the effectiveness of frequency filters in image processing will provide valuable information about the features of their application.

3.5.Gabor filter

The Gabor filter is obtained by modulating a sine wave with a Gaussian. For one-dimensional (1D) signals, the 1D sine wave is modulated by Gaussian. Therefore, this filter will respond to some frequency, but only in the localized part of the signal. Let *g (z)* - function that determines the Gabor filter, oriented to the beginning, with θ as a spatial frequency. We can view Gabor filters as:

$$g(z) = e^{-\frac{z^2}{2\sigma^2}} \cos(2\pi\theta z), \tag{2}$$

where σ^2 - the standard deviation of the Gaussian nucleus, which determines the amplitude of the function, θ - oscillation frequency, which is defined as $\theta = \frac{1}{T}$, where T is the period of the function $\cos(2\pi\theta z)$.

This formula is the product of a Gaussian and a periodic function, which involves the improvement of monotonic areas of periodic images. To apply filtering, you need to know the above parameters of the Gabor filter. In the case of fingerprints, it is assumed that the periodicity of the lines and the standard deviation are consistent mainly with the local characteristics of the image.

One of the difficulties of the Fourier transform is that the values of the Fourier coefficient depend on the whole image. All image pixels are used to calculate the Fourier image value of a single vector. If we think in terms of spatial frequencies, which are defined only locally, this phenomenon can be considered a change in the content of the image when moving on it. So, in some window around a point, narrow strips look with high spatial frequency, and wide strips - on the contrary, with low spatial frequency. Gabor filters do not have these shortcomings. Their nuclei look like elements of the Fourier basis multiplied by Gaussians. Thus, Gabor filters give a strong response at those points in the image where there is a component with local features of frequency in space and orientation.

A two-dimensional Gabor filter is used to filter the images. It is a harmonic function multiplied by the Gaussian function. The two-dimensional Gabor filter has the form

$$G(x, y, \lambda, \theta, \psi, \sigma, \varphi) = \exp\left(\frac{-x'^2 + \varphi^2 y'^2}{2\,\sigma^2}\right)\cos\left(\frac{2\pi x'}{\lambda + \psi}\right), \tag{3}$$

where

$x' = x\cos\theta + y\sin\theta,$
$y' = -x\sin\theta + y\cos\theta.$

In this equation (3) λ – wavelength of the cosine multiplier, θ – in degrees, ψ – phase shift in degrees, and φ – compression ratio [8]. The formula is the product of the Gaussian function and the periodic function, which is an improvement of the monotone regions of periodic images [9]. To apply filtering, you need to know the above parameters of the Gabor filter. For fingerprints, it is believed that the periodicity of the lines and standard deviations are consistent with the local characteristics of the image.

The bandwidth of the filter, which determines the frequency range to which the filter responds, is determined by the standard deviation parameters σ_x i σ_y. Since the bandwidth of the filter is set to match the local frequency of the spine, we can conclude that the choice of parameters σ_x i σ_y should be related to the frequency of the spine.

The disadvantage of using fixed values is that it forces the bandwidth to be constant, which does not take into account the options that may occur in the values of the frequency of the spine. For example, applying a constant bandwidth filter to a fingerprint image that shows significant changes in frequency values may result in uneven gain or other gain artifacts (Fig. 3). So instead of using fixed values, I chose a value 3/4x and 3/4y as functions of the spine frequency parameter, which are defined as:

$\sigma_x = k_x F(i,j)$
$\sigma_y = k_y F(i,j)$

where F – image of the frequency of the spine, k_x is a constant variable for σ_x, and k_y – constant variable for σ_y. This allows you to use a more customized approach because of value σ_x and σ_y fingerprint images can now be determined adaptively according to the local spine frequency. However, the print lines may have different orientations in different areas of the image, so it is necessary to find the orientation of the lines within each processed segment. Thus, the modified filter will be a function of three parameters $G(x, y, \theta)$.

Fig. 2. Fingerprint image taken with Gabor filtration result

The search for the orientation of the segment lines is implemented according to the algorithm described by Bazen [8]. The basic idea of the algorithm is that the gradient of the image, which corresponds to the differences from white to black, will be perpendicular to the lines on the fingerprints. In order for oppositely directed vectors not to compensate for each other during averaging, the so-called quadrature gradients are calculated [9]. Their directions are averaged in each area of the image, and then the corresponding angles of orientation of the fingerprint lines are calculated.

3.6. Binary image conversion

Binary conversion is the process of converting gray level images into binary images. There are only two levels in binary images, namely black pixels and white pixels, where the pixels show ridges and valleys in the fingerprint image. The value of pixel 0 is set in the black area of the fingerprint image, which represents the line of the ridges, and the value of pixel 1 identifies the white area in the image representing the valleys. The binary transformation approach is used to preserve the characteristics of the prints of the ridge structure and to eliminate some cohesion between the patterns.

The binarization process involves studying the value of the gray level of each pixel in the enhanced image, and if the value exceeds the overall threshold, the pixel value is set to a binary value; otherwise, it is set to zero. The result is a binary image containing two levels of information, foreground ridges and a background valley.

3.7. Thinning

The final stage of image improvement is usually performed before removing small details - thinning. Thinning is a morphological operation that successively erases foreground pixels until they are one pixel wide. A standard thinning algorithm is used, which performs a thinning operation.

4. CONDUCTING EXPERIMENTAL RESEARCH

The central part of the improvement algorithm lies in the Gabor filtering stage. This is the stage that performs the actual improvement of the fingerprint image. The purpose of the filtering stage is to increase the clarity of the vertebral structures while reducing noise in the image. In order to evaluate the efficiency of Gabor filtering, experiments were performed on both synthetic test images and real fingerprint images.

4.1. Choice of parameters

Gabor filter settings σ_x i σ_y control the bandwidth of the filter, and they should be chosen carefully, because they significantly affect the results of expansion. Value σ_x determines the degree of contrast between the ridges and valleys, and σ_y determines the amount of smoothing applied to the ridges along the local orientation. Fig. 3 shows the results of using different values σ_x and σ_y to apply the Gabor filter to the fingerprint image.

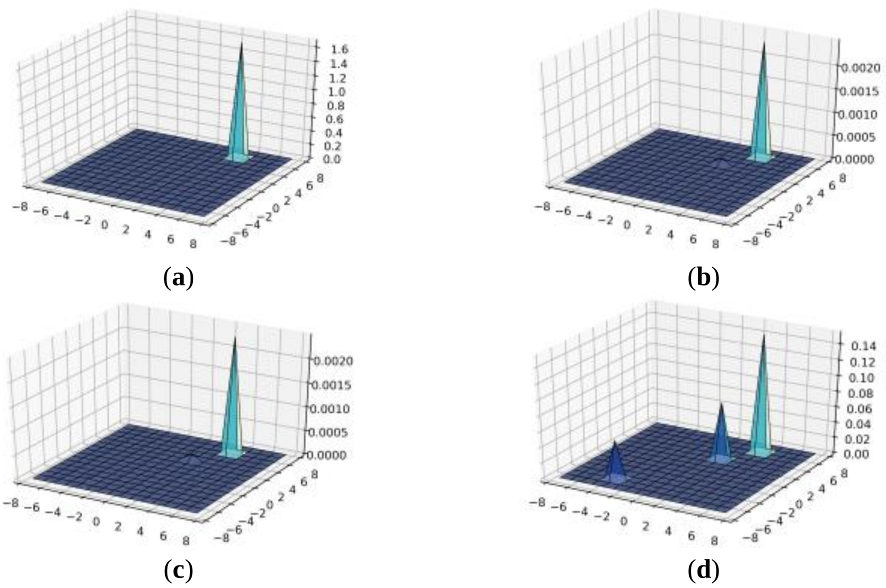


Fig 3. Construction of Ateb Gabor filter with parameters n=3, m=3; $\lambda = 2$ $\psi = 1$; in OX – x, in OY – y, a - σ =1; b - σ =2; c - σ =3; d - σ =4

Filtration of the two-dimensional Ateb-Gabor is implemented by formula:

$$Ateb\text{-}G(x,y,\lambda,\theta,\psi,\sigma,\zeta) = \exp(-(x'^2+\psi\cdot y'^2)/2\sigma^2)\ Ateb\text{-}ca(2\Pi\cdot x'/\lambda+\xi). \quad (4)$$

$x' = x\cos\theta + y\sin\theta$

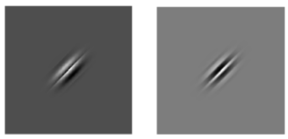
$y' = -x\sin\theta + y\cos\theta$,

where λ the wavelength of the cosine - multiplier, θ - parallel bandwidth normal orientation, ξ – lagging (phase transmition; phase shift) , ψ - data compression ratio.

4.2. Results of testing of artificial images

The results of applying the Gabor filter to synthetic noisy images are illustrated in Fig. 4 shows graphic representation of frequency two-dimensional Ateb-Gabor for a) *m*=0.1, *n*=1; b) *m*=0.5, *n*=1; c) *m*=1, *n*=1; d) *m*=3, *n*=1; e) *m*=2, *n*=1; f) *m*=4, *n*=1; g) *m*=5, *n*=1; h) *m*=1, *n*=5. This effective noise removal is partly due to the accurate estimation of orientation and frequency for less noisy images. On the other hand, when the filter is applied to images with high noise intensity (see Fig. 5), the results show that the filter is not able to effectively remove noise and produces a significant number of erroneous functions. This slight image improvement is due to an inaccurate estimate of the orientation and frequency of the spine that occurs at high noise levels, as shown in the previous sections.

a *b* *c* *d* *e* *f*



g *h*

Fig 4. Graphic representation of frequency two-dimensional Ateb-Gabor for a) *m*=0.1, *n*=1; b) *m*=0.5, *n*=1; c) *m*=1, *n*=1; d) *m*=3, *n*=1; e) *m*=2, *n*=1; f) *m*=4, *n*=1; g) *m*=5, *n*=1; h) *m*=1, *n*=5.

4.3 The results of filtering real fingerprint images

Fig. 5 shows the application of the Ateb-Gabor filter to the image of fingerprints of medium quality. The results of the improvement show that the filter maintains the continuity of the ridge structure and increases the clarity of the valley structure. In addition to reducing noise in the image, the filter is able to fill small gaps that occur within the ridges, as shown by enlarged areas of the image.

In contrast, the efficiency of the enhancement algorithm deteriorates when applied to low-quality images, as shown in Fig. 5. It can be seen that the filter has problems with areas of the image that are severely damaged, which leads to inefficient image improvement. Therefore, in practice, low quality images are usually discarded in fingerprint identification systems.

Fig 5. Ateb-Gabor filter to the image of fingerprints of medium quality

The results in Fig. 5 also show that although the clarity of the ridges is well enhanced, the gain at the points of the details is slightly blurred. The shape of the Gabor filter is designed to strengthen along the line of the ridges, parallel to each other and having a consistent orientation. However, detail points occur as local gaps in the flow of the fingerprint scheme, which can lead to incorrect estimation of local orientation and frequency. Therefore, compared to non-finite areas, the results of applying the filter to areas containing fine points are less effective for image enhancement.

CONCLUSIONS

The analysis of biometric information protection systems is carried out.

It has been found that it is more appropriate to use skeletons for complex transformations, as they allow the transformation of individual branches that are responsible for fragments of the object, without violating its integrity. The conversion error is minimal.

We have proposed Ateb-Gabor filtration, and based on filtration, thinning by the wave algorithm. This type of filtration will provide better characteristics, as it allows you to get more sloping shapes, to organize a wider range of curves.

Numerous experimental studies suggest the effectiveness of the proposed method.

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РОЗРОБКА МЕТОДІВ БІОМЕТРИЧНОЇ ІДЕНТИФІКАЦІЇ НА ОСНОВІ НОВИХ МЕТОДІВ ФІЛЬТРАЦІЇ

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Запропоновано метод біометричної ідентифікації, який будується на нових методах фільтрації. Зокрема розроблено фільтрацію біометричних зображень на основі Ateb-Габора. Метод базується на загальновідомому фільтрі Габора та дозволяє перебудовувати зображення із чіткішими контурами. Він має застосування до біометричних зображень, де створення чітких контурів є особливо актуальне. При фільтрації Габором відбувається реконструкція зображення шляхом множення гармонійної функції на функцію Гауса. Ateb-функції є узагальненням елементарної тригонометрії, і, відповідно, володіють більшою функціональністю. Фільтрування Ateb-Габора – це добуток Ateb-функції на на функцію Гауса. Фільтрування Ateb-Gabor дозволяє змінювати інтенсивність всього зображення, а також інтенсивність у певних діапазонах, і таким чином зробити певні ділянки зображення контрастнішими. Ateb-функції змінюються від двох раціональних параметрів, а це, в свою чергу, дає можливість гнучкіше керувати фільтрацією. Ще одним параметром, який впливає на фільтрацію є σ , що є середньоквадратичним відхиленням значень відносно її математичного сподівання. Першим кроком методу покращення відбитків пальців є сегментація зображення, де відбувається процес відокремлення ділянок переднього плану від фону. Далі відбувається зміна орієнтації, де визначається локальна орієнтація хребтів біометричного зображення. На наступному етапі – нормалізація, відбувається перерозподіл інтенсивності значень пікселів для забезпечення рівномірного зображення. При фільтрації намагаються досягти збільшення чіткості. Далі відбувається процес перетворення у бінарне зображення. На останньому етапі покращення біометричних зображень виконується потоншання - вилучення дрібних деталей. Ми запропонували фільтрацію Ateb-Габора на основі методів фільтрації та потоншання.

Keywords: фільтрування, фільтрування Ateb-Габора, біометричні зображення.

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