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The Comparison of the Efficiency of Using Gabor and Log-Gabor Filters to Create a Feature Vector in the Iris Recognition Task

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ABSTRACT: This paper compares the efficiency of using Gabor and Log-Gabor filters in order to create a feature vector from the iris image to tackle the recognition task. The efficiency of using Gabor and Log-Gabor filters in order to create a feature vector in the iris recognition task has been tested on the basis of CASIA-IrisV3-Lamp image database that consists of 16,213 images of people in different lighting conditions and camera focusing.

KEY WORDS: recognition, iris, Gabor filter, Log-Gabor filter, feature vector.

I.INTRODUCTION

In recent years, research has been actively conducted in the field of iris recognition [1]. The iris pattern is random in a greater or lesser degree, and the greater the degree of randomness is, the greater the likelihood that the pattern will be unique. The uniqueness of the iris pattern makes it possible to create highly reliable systems of biometric recognition. New, increasingly more advanced iris recognition systems are being developed [2, 3]. Most commercial systems are based on the technology developed by J. Daugman [4] and include the following stages: the iris outer and inner boundaries are distinguished in the initial grayscale image of an eye, then the iris is normalized (by means of geometric transformations of the iris into an annular-shaped template and then into a rectangular template of a fixed size). At the next stage, features are calculated using the Gabor filter, and the iris binary code is generated. Next, the resulting binary code is placed in correspondence with a specific user and entered into the database or can be used for subsequent comparison in the iris recognition procedure.

Being one of biometric technologies, the iris recognition is a promising method due to the fact that it is a non-contact method for data obtaining. To compare facial images, information about each image is presented in the form of a feature vector, and the method of its creation has a significant impact on the recognition results. Therefore, the task of a comparative study of different methods of creating the feature vector of the iris image is critical.

That being said, many methods for creating a feature vector for an image mainly use the Gabor filters, Hermite transform, Haar wavelets, etc.

In [5, 6], a method was proposed in which the normalized iris image is divided into 8 blocks, and Gabor filtering with 2, 4, 8, 16, 32 frequency parameters and possible rotation of the filter at 0°, 45°, 90°, 135° angles (20 filtered images are obtained per block) is implemented. For each filtered image, the average absolute deviation value is calculated, and this value is written to the feature vector. Feature vectors are compared using Euclidean distance. In [6], the image is divided into blocks 8x8 pixels in size; filtering with a Gabor function is performed in each block, and the feature vector contains both the average value and the average absolute deviation of the filtered functions.

In [7], it was proposed to distinguish the informative iris features by expanding the function of the iris intensity in a series of statistically independent functions. The expansion coefficients are quantized depending on the coefficient sign, and when comparing the irises, the binary coefficients are compared using the Hamming distance. A similar method was proposed in [8]. However, the Euclidean distance between the expansion coefficients is considered the measure of images proximity.

In [9–13], it was proposed to distinguish the most informative points of the iris texture in the iris image. In [9, 10], the authors identify key points using the Gabor filter. The image is divided into blocks, and in each block for the Gabor filter, frequency parameters 4, 8, 16, 32 and possible 0°, 45°, 90°, 135° angles are considered. In [9], the set of coordinates of key points serves as the iris feature vector, and the average Euclidean distance between the

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corresponding key points is calculated to determine the measure of the images proximity. In [10], the distances between key points located in this block and a point with averaged coordinates of all key points of this block are calculated as the iris feature vector for each image block.

Using the Gabor filters is one of the most common methods employed to create the feature vector of the iris image. The normalized iris image and the binary mask describing the useful and noisy (eyelashes, eyelids, glare, etc.) areas of the image are used as input information. The main advantage of the Gabor method used in this case is its ability to create a band-pass filter with tunable parameters. This property makes it possible to take into account the a priori characteristics of the analyzed object in the frequency domain. In imperfect conditions with the presence of correlated noise caused by a low-frequency difference in brightness, a higher recognition quality can be achieved when tuning a thin band-pass filter by optimizing its parameters. They are resistant to zoom, rotation, changes in brightness and contrast.

Gabor filters are special classes of band-pass filters capable of extracting frequency information in a limited spatial range. The filter responds to the frequencies of a given spectrum in a specific spatial region.

In this paper, we compare the efficiency of using the Gabor and Log-Gabor filters to further create a feature vector from the iris image to tackle the recognition task.

II. THE GABOR FILTER

Being band-pass ones, Gabor filters reveal the frequency range of a signal in a certain range and direction. The Gabor filter kernel is calculated by the formula [14]:

$$g(x,y;\lambda,\theta,\psi,\sigma,\gamma)=\exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\psi\right),$$
$$x' = x\cos\theta + y\sin\theta,$$
$$y' = -x\sin\theta + y\sin\theta. \quad (1)$$

Where λ is the wavelength of the cosine factor; θ represents the orientation of the normal to the parallel bands of the Gabor function in degrees; ψ is the phase offset in degrees; γ is the spatial aspect ratio, and specifies the ellipticity of the Gabor function.

The calculation results can be presented in the form of the real (Figure 1.) and imaginary (Figure 2.) parts of the image.

Figure 1. The real part of the filtered image

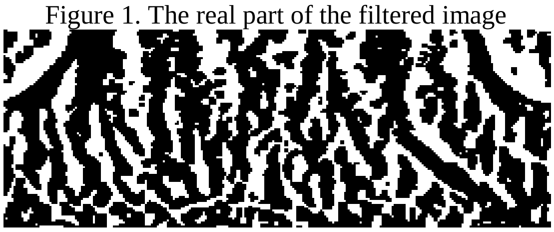

Figure 2. The imaginary part of the filtered image

The phase characteristic is defined as [3]:

$$\theta = \arctan\left(\frac{\mathrm{Im}}{Rm}\right) \quad (2)$$

where Im and Rm are the real and imaginary parts of the filtered image, respectively.

The transition to the phase characteristic of the Gabor filter is selected for the following reasons: the phase is less dependent on brightness variations, respectively, is a more stable image characteristic.

The bitmap obtained a result of the calculation of the Gabor filter phase is shown in Figure 3.

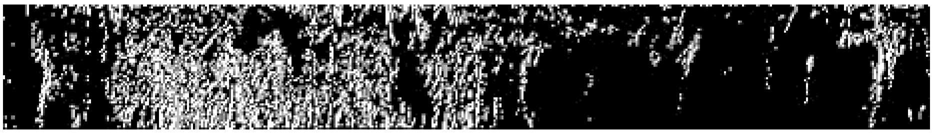

Figure 3. The Phase characteristic of the Gabor filter

III. THE LOG-GABOR FILTER

The Log-Gabor filter is a modification of the Gabor filter. Its distinguishing feature is the use of the logarithm function in the formula for building kernels [14]. The kernel building function can be written as follows:

$$G_{(s,t)}(\rho,\theta)=\exp\left(\frac{-(\rho-\rho_0)^2}{2\sigma_\rho^2}\right)\exp\left(\frac{-(\theta-\theta_{(s,t)})^2}{2\sigma_\theta^2}\right)$$

$$\begin{cases}\rho_s=\log_2 n-s\\ \theta_{s,t}=\begin{cases}\dfrac{\pi}{n_1}t, & \text{if } s \text{ is odd}\\ \dfrac{\pi}{n_1}\left(t+\dfrac{1}{2}\right), & \text{if } s \text{ is even}\end{cases}\end{cases} \quad (3)$$

where ρ and θ are log – polar coordinates; s is the size index; t is the rotation index; n_1 is the maximum rotation index; the pair ρ_k and $\theta_{s,t}$ specifies the frequency center of the filter; σ_ρ and σ_θ specify the angular and radial widths of the bands.

IV. EXPERIMENTAL RESULTS

The CASIA image database [16] is the most widely used for research in the field of iris recognition. For research purposes, it is provided free of charge. Therefore, this database was chosen as the main one for testing the developed algorithms as part of the dissertation. All images were recorded in the near infrared range, the brightness depth is 8 bits/px, the file format is JPEG. CASIA image base has three versions. We used the third version for testing.

The third version of the CASIA image database is divided into three image groups: the CASIA Interval image database (320×280 px), the CASIA Lamp image database (640×480 px), the CASIA Twins image database (640×480 px). The CASIA Interval image database contains 2655 eye images (249 objects). The CASIA Lamp image database was obtained in one session and contains 411 objects, 819 classes, 16,213 images. CASIA Twins image database is the first image database containing the iris images the twins (100 pairs of twins) and obtained in one session, 200 objects, 400 classes, 3,183 images.

Testing was performed on high-resolution eye images (the radius of the iris is more than 500 and 1000 pixels), as well as on the publicly available database of eye images with standard resolution - CASIA-IrisV3-Lamp (radius of the iris is 90-110 pixels). Figure 4 shows some examples of images from the CASIA-IrisV3-Lamp database.

To evaluate the efficiency, we used statistical indicators such as type I error (false rejection, FRR), type II error (false acceptance, FAR) and a recognition error measure that is adequate to the equal probability of types I and II errors (EER). The lower the EER, the more efficient the recognition algorithm is. The method was compared with the basic approach with an octave frequency increase (OFE) described in [15]. The Hamming Distance (HD) was selected as a measure of the difference in pairs of the iris feature vectors. The results are presented in Table 1.

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Figure 4 – Examples of images from the CASIA-IrisV3-Lamp database

Table 1
Comparison of recognition efficiency when using the Gabor and Log-Gabor filters

Filters	**EER**	**Processing time**
Gabor filter	0.011681	0.165
Log-Gabor filter	0.009254	0.145

V.CONCLUSION

As a result of the work done, two methods of image filtering were compared to further create the feature vector from the iris image in order to tackle the recognition task. From the data presented in table 1, it follows that the Log-Gabor filter makes it possible to achieve a better result as compared with the Gabor filter, while spending less time.

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