Method of preliminary localization of the iris in biometric access control systems

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Abstract. This paper presents a method of preliminary localization of the iris, based on the stable brightness features of the iris in images of the eye. In tests on images of eyes from publicly available databases method showed good accuracy and speed compared to existing methods preliminary localization.

1. Introduction
At the present time, biometric authentication systems have found wide acceptance as a result of technological advances and an increase in computing capacity. These systems allow to identify the users by certain biometric parameters. A biometric parameter may be a fingerprint, a hand shape, an iris pattern and so on. Basic requirements for a biometric parameter include versatility, stability within a longer period of time, and access for scanning. Parameters of texture determined by mathematical and physical methods used for inhomogeneous structures [1,2].

The iris identification is not a trivial task and includes several phases:

- taking eye pictures with a special scanner;
- iris localization in the picture;
- normalization of the localized iris;
- extraction of feature vectors;
- comparison of feature vectors.

One of the most difficult and labor-intensive phases of the recognition is the iris localization in the picture. The reason is that the position, the angle of rotation and slope of the iris are not stable and can vary greatly. Besides, the localization process gets complicated by factors such as pupil dilation, closing a part of the iris by lids, eyelashes, and fine white lines. At this moment, there are many iris localization methods and algorithms. One of the best known and proven methods is using the Daugman's integro-differential operator to approximate the inner and outer iris boundaries. There are other methods used for iris localization as well, for example, the Hough transformation method for searching the circumference, the method of active circuits and so on.

For most of these methods, it is necessary to establish the initial and terminal conditions, such as the initial searching point (it may coincide with the approximate pupil center), the minimum and

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maximum radii of the inner and outer iris boundaries, and the search area. Without these parameters the search is not efficient.

The work objective is to develop a new method of the preliminary localization by pinpointing the location of the iris in an effort to increase efficiency.

Tasks:

1. To analyze current methods of the preliminary iris recognition.
2. To develop a method to increase the iris recognition.
3. To apply the method on the iris test pictures from databases publicly available.

In several cases, the method of brightness’ projection [3] is used to define the initial search point. The essence of the method: the pupil of most people has the form closely resembling a circle, which allows searching for it as a dark circle on the image.

The clusterization of images is performed [4]. On the image of an eye, the areas of eyebrows, skin, sclera, and iris are differentiated. This allows narrowing the search area and increasing its accuracy.

2. Proposed approach
In this publication, a new method of the preliminary search for the iris is offered. The essence of the method: the iris on the image has a series of consistent characteristics that can be used for a preliminary search. It is well known, that the area surrounding the iris has a higher brightness in most cases. At the same time, the pupil inside the iris is darker. Such brightness variations between an eye’s elements allow selecting a steady pattern, on which to base the search for an iris.

An eye image considered a two-dimensional function of the brightness $I(x, y)$. Let us think of a two-dimensional function as a set of one-dimensional functions $I_y(x)$. In other words, a two-dimensional image is divided into a sequence of horizontal stripes.

The signal has to undergo a low-pass filtering to eliminate noise and undesirable details. For this purpose the Gaussian filter can be used.

The upper boundary of the brightness range must be cut off as well to eliminate the influence of flares in the search.

However, not the brightness function $I_y(x)$, but its first derived function $I'_y(x)$, is the most informative. This function allows identifying the boundaries of transition between the sclera and the iris, and between the iris and the pupil. (picture 1).

On the derived function $I'_y(x)$ the sequence of peaks is searched for. The peaks have to meet the criteria as follows:

1. The derivate has a negative value on the boundary of transition from the light sclera to the darker iris and from the iris to the darker pupil, the opposite is as well:
   \[ I'_y(x_1), I'_y(x_2) < 0, I'_y(x_3), I'_y(x_4) > 0 \]

2. The boundaries of transition from the sclera to the iris, from the iris to the left and right pupil must have values close to the module’s:
   \[ \left\| I'_y(x_1) - I'_y(x_2) \right\| < \varepsilon, \left\| I'_y(x_3) - I'_y(x_4) \right\| < \varepsilon, \]
   where $\varepsilon$ is some value that determines an acceptable deviation level. This value is due to heterogeneity of illumination (under ideal conditions $\varepsilon$ is very close to zero).

3. The relation between the diameters of the iris and the pupil is established as:
   \[ k_{min} d_p < d_p < k_{max} d_p, \]
   where $k_{min}$, $k_{max}$ are the coefficients that define the maximum possible pupil dilation and the
minimum possible contraction of the pupil with respect to the diameter of an iris. They depend on anatomic features of the eye [5].

Besides, proximate to \( I_{y} (x) \), for \( I_{y-l} (x) \) and \( I_{y+l} (x) \), where \( l \) is a certain constant, the criteria quoted above should be met as well, while the values of \( x_{1} \) and \( x_{2} \) with \( I_{y-l} (x) \) and \( I_{y+l} (x) \) should be greater than with \( I_{y} (x) \). In the same way, the values of \( x_{3} \) and \( x_{4} \) should be smaller.

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**Figure 1.** a) The artistic rendition of the iris with the line \( I_{y} (x) \) that goes through the pupil’s center. b) Diagram of values of the \( I_{y} (x) \) function. c) Diagram of values of the derived function \( I_{y} (x) \).
After the determination of the pattern and the points \( x_1, x_2, x_3, x_4 \), the assumed values of the iris boundaries are calculated: the coordinates of the center \((x_p, y_p)\) and the radius \(r_p\) of the pupil, the coordinates of the center \((x_i, y_i)\) and the radius \(r_i\) of the outer boundary of the iris.

The result of the method described above should produce a list of prospects \((x_p, y_p, r_p, x_i, y_i, r_i)\).

After that, the boundaries are specified for each candidate by the Daugman's integro-differential operator, whereupon candidates with the maximum value of the Daugman's operators are picked up.

The essence of the method, as applied to the real eye image, is shown on picture 2. The areas of the sclera, the iris, and the pupil can be extracted on the brightness function diagrams. On the derivative diagram, the peaks by the coordinates that coincide with the inner and outer boundaries of the iris can be seen. The obtained values allow identifying the areas of search for the iris, as well as the approximate coordinates of the pupil and the iris.

3. Results and discussion
The database system [6] was used for the purpose of the test. The Daugman's integro-differential operator was applied as the specifying method for localization.

For checking purposes, the tests were performed using the databases UTIRIS [7] and CASIA Iris Image Database (version 1.0) [8]. For each image, the automatic iris localization was performed. The results of the automatic and manual localizations were compared. The outcome of experiment is shown in Table 1.

| Name of the database | Number of shots for the test | Accuracy, % |
|----------------------|-----------------------------|-------------|
| UTIRIS               | 100                         | 97          |
| CASIA Iris Image Database (version 1.0) | 100 | 90 |

When testing the method on images from the CASIA Iris Image Database (version 1.0) the accuracy was lower. This is due to the fact, that in some cases the boundaries between the sclera and the iris are scarcely distinguishable. For this reason they are considered false extrema during the analysis.

During the experiment, the speed of localization of the iris of the methods of brightness projection and of the offered method was compared. The Daugman's integro-differential operator was applied as the specifying method for localization. The results are shown in Table 2.

Also during the check of localization speed, iris was compared to the preliminary use of the method of brightness projection and the offered method

| Name of the database | Average processing rate, ms |
|----------------------|-----------------------------|
| Brightness' projection | Offered method |
| UTIRIS               | 65                          | 48          |
| CASIA Iris Image Database (version 1.0) | 52 | 25 |

As Table 2 shows, the localization speed of the offered method is higher. This is because the boundary conditions for the search are set more precisely.

4. Conclusions
The offered method of the preliminary search allows narrowing the iris recognition area. This method decreases the time of the current recognition methods.
Figure 2. How the method works. a) The initial image of the eye. b) The smoothed image of the eye with marked boundaries. The red line marks a single line taken for the analysis. c) The brightness diagram from the coordinate x taken for the band of the image. d) The diagram of the brightness function is derived by the coordinate x taken for the band of the image.

The test results have shown, that the application of the offered method, compared to the method of brightness’ projection, allows speeding up the work involved in iris recognition.
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