Detection of iris in image by interrelated maxima of brightness gradient projections

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Abstract

A method is proposed to detect a human iris location and size in digital image given some point lying inside the pupil. Method is based on construction of histogram projections of local brightness gradients and interrelating local maxima of these histograms as probable positions of pupil and iris borders. Method is characterized by low calculation cost and high stability against noise.

Keywords: *iris identification, image processing, brightness gradient, image projection*

1. INTRODUCTION

Recognition of human by iris is one of the most demanded biometric technologies. Algorithm of iris size and position estimation is an essential part of iris registration systems. Since outer borders for both pupil and iris can be approximated by circles with good precision, circle detection is a central element of any system of iris detection in image. There are plenty of methods of circle (or circumference) detection implemented and tested for this task: detecting of mass center of an object selected by thresholding function [1], detection of a point most remote from borders of such selected object [2], maximizing of integro-differential circular symmetric operator [3], generalized [4] and split [6] Hough transform, Hough transform using brightness gradient [8], brightness gradient projection method [9], paired gradient vectors [10], circular shortest path construction [7], restoring centers of circles passing through randomly selected points [5]. However, so far the fact was not employed that iris border contains two circles (pupil-iris and iris-sclera borders) with interrelated parameters. Synchronous detection of two circles with parameters subject to certain mutual restrictions, implied by nature of iris allows substantially enhance algorithm characteristics in comparison with search of single circle. A proposed algorithm of iris location is based on construction of histograms (local brightness gradient circular projections) and comparisons of their maxima as possible positions of iris borders.

2. CONSTRUCTION OF CIRCULAR PROJECTIONS OF BRIGHTNESS GRADIENT

As in majority of recognition tasks the problem of iris location can be treated as a problem of selection of best positions of the two circles from a set of alternatives. These alternatives are given by positions of maxima of circular projections of brightness gradient. These projections are constructed relative to an approximate iris center, as detected in [9].

Input data for the algorithm are monochrome eye image and an approximate position of eye center. Irises with diameter not exceeding image size can be detected.

Denote: $\mathbf{c} = (c_x \quad c_y)^T$ be a point of approximate center position. Method [9] guarantees its distance to real pupil center is not greater than half of pupil's radius. For simplicity consider this point as a coordinate origin. $\mathbf{x} = (x \quad y)^T$ is a point vector, $b(\mathbf{x})$ is a brightness (intensity) in this point, $\mathbf{g}(\mathbf{x}) = \nabla b(\mathbf{x})$ is a brightness gradient.

Only points with certain gradient value and direction can belong to iris border. This set is described by indicator function:

$$v_U(\mathbf{x}) = \begin{cases} 1, & \|\mathbf{g}\| > T_1,\ T_2 < \dfrac{\mathbf{x}\cdot\mathbf{g}}{\|\mathbf{x}\|\ \|\mathbf{g}\|} < T_3,\ U \\ 0, & \textit{otherwise} \end{cases},$$

where T_1, T_2, T_3 are thresholds established according to characteristics of input image, U is an additional condition selecting a sector (quadrant) of the coordinate plane. For instance, right quadrant is given by condition $U \equiv R : |x| > |y|, x > 0$. Taking one of such conditions for $v_U(\mathbf{x})$ one can obtain a histogram of number of points satisfying the conditions as a function of radius. For example the following is a histogram of right quadrant normalized to radius:

$$\Pi_R(r) = \frac{1}{2\pi r} \sum_{r-0.5<\|\mathbf{x}\|<r+0.5} v_R(\mathbf{x}).$$

Fig.1. represents eye image and its right quadrant histogram $\Pi_R(r)$. Eight local maxima positions $\arg loc \max_{n,r} \Pi_R(r)$, n=1…8 are outlined in the histogram there.

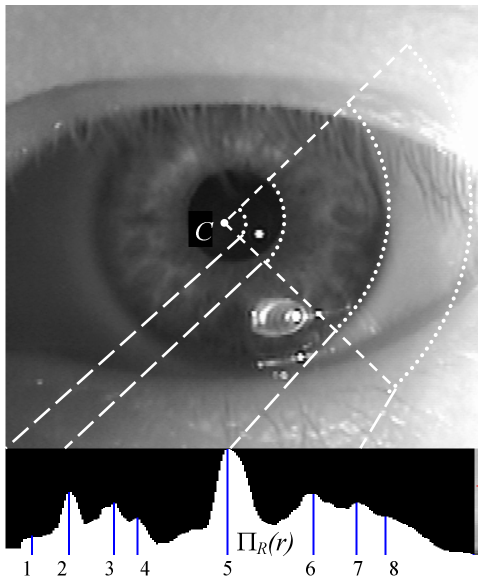

Fig.1. **Sample of circular projection and local maxima positions**

After detecting local maxima positions for all four quadrants one can obtain distances to hypothetic circle borders from central point in appropriate direction.

Combining these values one can obtain coordinates of centers $\mathbf{q} = \begin{pmatrix} q_x & q_y \end{pmatrix}^T$ and radii ρ of these circles:

$$q_x^{n,m} = \frac{1}{2}\left(\arg \underset{n,r}{loc\max}\, \Pi_R(r) - \arg \underset{m,r}{loc\max}\, \Pi_L(r)\right).$$

$$q_y^{u,v} = \frac{1}{2}\left(\arg \underset{u,r}{loc\max}\, \Pi_T(r) - \arg \underset{v,r}{loc\max}\, \Pi_B(r)\right)$$

$$\rho^{n,m,u,v} = \frac{1}{4}\begin{pmatrix} \arg \underset{n,r}{loc\max}\, \Pi_R(r) + \arg \underset{m,r}{loc\max}\, \Pi_L(r) + \\ \arg \underset{u,r}{loc\max}\, \Pi_T(r) + \arg \underset{v,r}{loc\max}\, \Pi_B(r) \end{pmatrix}$$

Quality of circle obtained for four given positions of local maxima (n, m, u, v) may be estimated as sum of projection function values in these positions.

3. SELECTION OF INTERRELATED HISTOGRAM MAXIMA

So, various hypothetic circles are constructed by a method of circular projections. The circles can be hypothetic pupils (index P is used further) or irises (index I). Circles can be defined by their parameters, center position and radius: $(\mathbf{q}_P, r_P)$ и $(\mathbf{q}_I, r_I)$. If two circles are the borders of an iris the following limitations due to human iris nature are necessarily true:

1) $r_P > \frac{1}{6} r_I$ (iris radius cannot exceed pupil more than six times)

2) $r_P < \frac{3}{4} r_I$ (pupil radius cannot be bigger than 75% of iris)

3) $d < r_P$, $d = \|\mathbf{q}_P - \mathbf{q}_I\|$ iris center lies inside pupil circle

4) $2(r_I - r_p - d) > r_I - r_P + d$, or after reduction $d < \frac{r_I - r_P}{3}$, (Lengths of segments between pupil and iris borders cut by a line passing through pupil and iris centers do not differ by more than two times).

From all pairs of circles satisfying (1-4) the one is selected with maximum sum of quality values.

Thus algorithm in whole consists of four steps:

- calculation of local gradients in image
- building circular projections (histograms) for four quadrants
- selecting local maxima in histograms
- enumeration of circle combinations searching most likely (with biggest quality) pair.

4. EXPERIMENTS

The following databases from public domain were used for performing experimental study: UBIRIS (http://www.di.ubi.pt/~hugomcp/doc/ubiris.pdf , 1207 images), CASIA Iris Image Database (http://www.sinobiometrics.com , 16213 images) and Iris Challenge Evaluation (http://iris.nist.gov/ice/ , 2954 images). Size of these images is 640*480 pixels, iris radii vary from 50 to 200 pixels.

Testing method. Eye images were reviewed by human expert who indicated pupil and iris borders in each of them. These data were then considered as true and were used for method verification. Then images were processed automatically. The approximate eye center was detected by method [9] (this point rarely matches true pupil center or true iris center, but is always close to them). With the help of method proposed here pupil and iris were detected. Their parameters were compared with those indicated by human operator. Table below gives numbers of rude errors (difference in any one of center coordinates or radii exceeds 10 pixels) and moderate (difference in any one of center coordinates or radii exceeds 5 pixels) errors. If all parameter values differ from true one not more than by five pixels, detection is considered correct.

Table. Results of algorithm for test databases.

Data base	Image count	Number of moderate errors in pupil	Number of rude errors in pupil	Number of moderate errors in iris	Number of rude errors in iris
UBIRIS	1207	315	3	32	1
CASIA	16213	1916	31	212	20
ICE	2954	112	7	9	2

Execution of the algorithm takes not more than 0.01 second in PC with P-IV 3GHz CPU for an image of 640*480 pixels. Main share of calculation time is taken by Sobel gradient estimation.

Proposed method of iris location may be applied for preliminary determination of pupil (with precision up to 5 pixels) and iris (with precision up to 10 pixels) positions if a point lying inside pupil is known. Method is useful for real-time applications.

5. LITERATURE

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