Automatic Methods for Determining the Characteristic Points in Face Image

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Abstract. There are described in this paper algorithms of extract the characteristic points in a face image with complex background. Presented algorithms combine known tasks of image processing and developed procedures. Novel peculiarity of the method, in comparision to the methods described in the existing literature, is using its own algorithms for edge detection of iris and eyelid edges. The methods for automatic face location, eyes, eye iris, corners of eyes, edges of the eyelids, corners of lip and external edges of lip location - were described and developed. The part of the work dealing with face recognition was based on the technique of automatic authentication of a person with assumption of the use of automatically extracted, structural characteristics of the leads for the biometrical authentication systems' improvement. Achieved results are satisfactory for purpose of use in developed face recognition methods.

Keywords: face localisation, face recognition, iris detection, edges of the eyelids detection, lip corner detection, edges of lip detection.

1 Introduction

Nowodays face and characteristic points in face image detection methods have wide scope of use in many computer vision applications, such as systems of human-computer interaction [1,2]. Significant part of applications is used in systems for face recognition in access control and model-based video coding [2,3].

Automatically location of the face and facial characteristic points allows the building of biometric systems that may successfully carry out the identification, verification of people and for example lip reading.

The first step is to locate face area on image. This is done by algorithm combining skin-like color detection method [4], median filtering and simple method of determining region boundaries. Once the face has been detected the nex step is to locate both eyes' area. For purpose of detecting eyes the 3-stage gray-level image projection algorithm was applied. The iris detection has been accomplished - through combining gray-level image thresholding (with automated threshold selection), median filtering, *Canny* edge detection and procedure of

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finding circles in eye's edge-image. Similarly, the edge of the eyelid detection is implemented. Detection of outer edges and corners of mouth based on color image is realized.

2 Face Detection and Eyes Localisation

Frontal face image was assumed as an input of face recognition procedure to have an *RGB* color space. The algorithm of thresholding in *I2* color space was applied for enabling face detecting in an input image [4,6]. The *I2* color space enables to detect skin-like color regions in input *RGB* image with satisfactory result.

To transform image to *I2* color space, we have to subtract R and B components of *RGB* space. Both components are dependent on G component. Dividing the components R and B by the component G significantly reduces light changes' impact on the method correctness. Similarly the reduction of lighting effects to the method's quality, gives *HSV* color space application. That has been also implemented in our system. Let I_R, I_G and I_B represent matrix containing R, G and B components respectively, for each pixel of input image. The output I_{RB} matrix we can obtain after subtraction:

$$I_{RB}[i][j] = \sum_{i=0}^{w} \sum_{j=0}^{h} \frac{I_R[i][j] - I_B[i][j]}{I_G[i][j]} \tag{1}$$

where: w,h - width and height of input image.

Once we have an *I2* color space image the next step is to apply thresholding procedure which may be described by following formula:

$$I'[x][y] = \begin{cases} 255 \text{ for } I_{RB}[x][y] > T \\ \;\;0 \;\;\text{ for } I_{RB}[x][y] \leq T \end{cases} \tag{2}$$

where: $x = 0...w$, y $= 0...h$ - coordinates of the pixel, w,h - width and height of the image, I_{RB} - input *I2* color space matrix, *I'* - output, thresholding image and T - threshold.

The modified median filtering procedure was applied - in order to eliminate noise around the face area and small objects in background. In classic median filtering values of pixels neighborning analyzed pixel (including analyzed pixel) are sorted from lowest to highest (or reverse). The median value of surroundings pixels is being assigned and to analyzed pixel [6]. The result of modified median filtering is image with smoothed edges of face area. Also small background objects were eliminated.

The boundaries of face region are acquired in simple procedure. The upper boundary is the row of image where number of white pixels (occuring continously) exceeds given value. The lower boundary - the line where number of white pixels decreases below given value. Vertical boundaries are white pixels found most on left and right side of the image (in limits of horizontal boundaries).

It has been possible to search the pupils by looking for two dark regions lying within a certain area of the face. There are applied Gradient Method and Integral Projection (GMIP) [4] to find horizontal *(h line)* and vertical (*v line 1, v line 2*) line of eyes. Before that, the image face is converted to the grayscale. Following equations (3,4,5) describe way of finding the pupils.

$$h\ line = \max_i \left(\sum_{j=1}^{w-1} |im_{i,j} - im_{i,j+1}| \,,\ i = 1..h \right) \tag{3}$$

$$v\ line\ 1 = \max_j \left(\sum_{i=h\ line-t}^{2t} |im_{i,j} - im_{i+1,j}| \,,\ j = 1..\frac{w}{2} \right) \tag{4}$$

$$v\ line\ 2 = \max_j \left(\sum_{i=h\ line-t}^{2t} |im_{i,j} - im_{i+1,j}| \,,\ j = \frac{w}{2} + 1..w \right) \tag{5}$$

where: w - width of image im in pixels, h - height of image im in pixels, t - half of the section containing the eye area.

To search the lips initially, the approximate positions of the corners of mouth are predicted, using the positions of the eyes, the model of face and the assumption, therefore one should to have a near frontal view. Fig. 1 shows example of eyes localisation and area of mouth detection on basic of eyes position

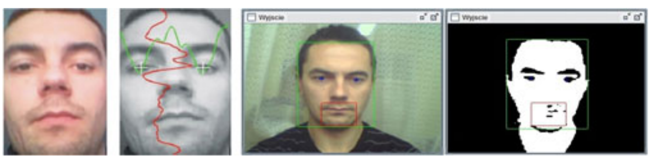

Fig. 1. Example of ayes localisation and area of mouth detection on basic of eyes position

3 The Mechanism of Iris Detection

We have to find circle circumscribed about the iris on area containing image of the eye (see Fig. 2). This task may be completed in following steps.

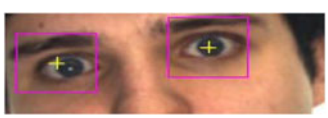

Fig. 2. Determined area containing image of the eye

First step: Thresholding the gray-level image with automatically selected threshold and applying Canny edge detection procedure. In our procedure value of threshold is set as average value of pixels in analyzed image incremented by constant (101, this constans was determined experimentally). The threshold value is calculated using the relationship:

$$T = 1 + \frac{1}{w \cdot h} \sum_{x=1}^{w} \sum_{y=1}^{h} I[x][y] \tag{6}$$

After applying threshold, the median filtering procedure was used (see section 2). Next, there was applied the Canny edge detection procedure. Stage of Gaussian filtering was omitted due to reducing edge sharpness. Image of the eye after edge detection is shown on Fig. 3

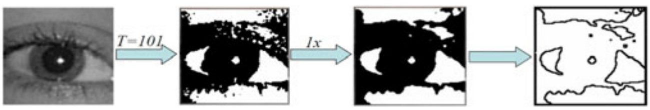

Fig. 3. Processed eye image before and after Canny edge detection procedure

Second step: Finding points on edge of tge iris and determining best-fitted circle. We use 10 rays with center in point of maximum projection in order to detect edge of the iris (see section 2). The rays are inclined at angles of: 340^o, 350^o, 0^o, 10^o, 20^o, 160^o, 170^o, 180^o, 190^o, 200^o. In range of 20 to 65 pixels from the center, along each ray we find first occurrence of black pixel and set it as edge of the iris. This gives us set of 10 points - candidates for circle circumscribed about the iris. Result of above procedure is presented if Fig. 4. Next step is to verify which points belong to iris circle.

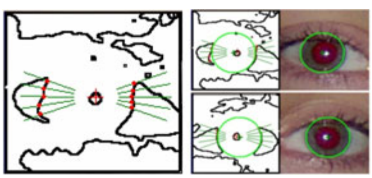

Fig. 4. Result of finding point on edge of the iris

4 The Mechanism of Edges of the Eyelids Detection

After determining the position and shape of the iris, the next step is to extract characteristics eyes - to determine the shape of the upper and lower eyelids. It is assumed that the shape edges of both eyes will be approximated third-degree polynomials.

In order to extract the edge of the eyelid, method based on processing information about the luminance image (LM - Luminance Minimum and ILP - Interval Luminance Projection) and based on an analysis of the space (R/G, B/G) was proposed. Information about the luminance was collected from the image represented in space RGB according to the rule:

$$Y = 0,299 \cdot R + 0,587 \cdot G + 0,114 \cdot B \tag{7}$$

With such representation of the eye area, we can easily distinguish the edge of the eyelid, searching the smallest value of luminance in the vicinity of the iris.

To seek internal and external corner of the eye separate areas were designated. When setting the initial eye corners, there were adopted points contained in the extreme positions to the left and the right in the search areas [7]. Fig. 5 shows separate areas, luminance levels for the eye and pre-set eye corners.

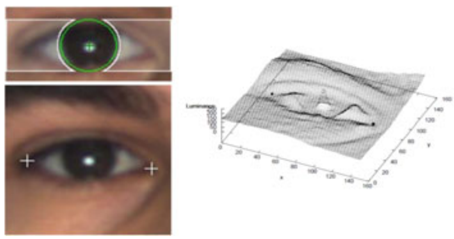

Fig. 5. Separate areas, luminance levels for the eye and pre-set eye corners

In order to determine points located on the edge of the upper eyelid, in the matrix luminance there were searched values of local minima starting from the point of the outer corner of the eye. Because of the unreliability of the method for images with large differences in values luminance at the edge of the eye, RGBG procedure based on image processing in space (R/G, B/G) was proposed. Analysis of the components of such a space allows accurate separation of areas with a specific color, depending on the adopted threshold. Using the method of least squares, based on the found items, set the shape of the polynomials approximated edge of eyelids. After the appointment of polynomials for the upper and lower eyelids, as the final corners of the eye, the nearest of the pupil intersections of polynomials was adopted [7]. Fig. 6 shows threshold in the space (R/G, B/G) and the designated edges of eyelids.

5 The Mechanism of Mouth Detection

To search the lips initially, the approximate positions of the lip's corners were predicted, using the position of eyes, the face's model and the assumption, therefore one should to have a near frontal view. Exact finding of corners of mouth was very important because the edge of mouth would be defined on basis of corners of mouth. In this work, there was assumed that one should has appointed only external edges of mouth.

Fig. 6. Threshold in the space (R/G, B/G) and the designated edges of eyelids

The position of mouth corners may be found through the application of the own method of finding mouth corners. The mouth corners are defined on basic of specific mouth color and specific mouth shape (Color and Shape of Mouth, CSM) [5]. First, the mouth position is found using specific color, and then mouth corners are defined as extreme points of situated mouth. To qualification of specific mouth color, video frame is spreaded on component RGB. Then, for mouth color MA it's accepted area, in which:

$$MA = \begin{cases} \frac{R}{G} - \frac{B}{G} < T1 \\ \text{and} \\ \frac{R}{B} - \frac{G}{B} < T2 \end{cases} \tag{8}$$

One should $T1$ and $T2$ to accept experimental.

Having definite mouth area and mouth corners, it is possible to mark external mouth edges (Lip Contour Detection, LCD) [5]. On basis of mouth corners resource of circle is defined, for which what α a ray is drawn, beginning from one from appointed corners of mouth. It's got $2\pi/\alpha$ of rays. Moving oneself along every from rays in direction of resource of circle, points are marked where appointed earlier area of mouth MA begins [5]. Fig. 7 shows scheme of assumed visual motion of mouth, location of corners of mouth and definition of external edges of mouth.

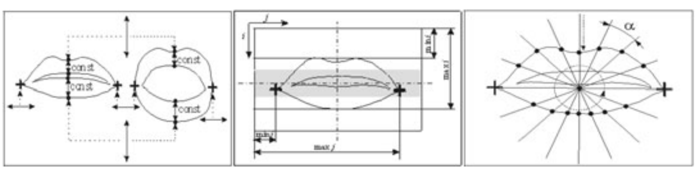

Fig. 7. Scheme of assumed visual motion of mouth, location of corners of mouth and definition of external edges of mouth

In order to eliminate significant mistakes, each of appointed points is being compared with neighboring points, and suitably modified. In dependence from settle angle of jump α there are received $2\pi/\alpha$ points [5]. One should α to accept experimental. It was accepted $\alpha = 2/16$. Fig. 8 shows examples of appointed corners and external edges of mouth.

Fig. 8. Examples of appointed corners and external edges of mouth

6 Experimental Results

In first experiment, effectiveness of the method of location of corners of the eyes and effectiveness of the method of location of corners of the eyes was tested. It was tested twenty different persons, recorded by the camera. Every recording contained about 100 frames/s, so it was tested near 2000 video frames. For every frame box, corners of eyes and corners of mouth were marked by hand, and next this corners were compared with automatically situated corners of eyes and corners of mouth respectively, received by using the automatic location of corners of the eyes and corners of mouth. Tab. 1 shows shows results of first experiment.

Table 1. Average vertical and horizontal incorrect location of corners of the eyes and corners of mouth in pixel

method	amount of frames	error x [pixels]	error y [pixels]
corners of the eyes location	2000	5,3	7,1
corners of mouth location	2000	4,8	5,7

In second experiment the effectiveness of edge detection of the eyelids and the lips were tested. There were tested also twenty different persons, recorded by the camera. Each recorded frame box was checked, defining membership of recognized object to object correct object, incorrect object (+) and incorrect object (-). Incorect object (+) marks, that corners became recognized correctly and incorrect object (-) marks, that corners became recognized irregularly. Tab. 2 shows results of eyelids and lip tracking in real-time.

Table 2. Result of eyelids and lip tracking in real-time

method	amount of frames	correct object [%]	incorrect object (+) [%]	incorrect object (-) [%]
edges of eyelids location	2000	87,7	3,4	8,9
edges of lips location	2000	92,2	2,2	5,6

7 Conclusion and Future Work

There were presented in this paper methods for automatic face location, eyes, eye iris, corners of eyes, edges of the eyelids, corners of lip and external edges of lip location. The main aim was to show how to locate specific points on the human face automatically. Presented methods give satisfactory results in aim of future processing in person verification system based on facial asymmetry and tracking of characteristic points on human face. A major defect of the methods is the manual selection of threshold values. The methods would be improved by realization of automated threshold selection.

Described methods have already been partially implemented in our system. In future, we plan to build the system for identification and verification identity of users, based on the automatic location of a human face and its characteristic features. Main aim would be to implement elements of the face location based on gray-scale images and immunization of the system to a variable value of lighting. Destiny of the created system would be working in close-circuit television systems.

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