# An Algorithm for real time eye detection in face images

T. D'Orazio, M. Leo, G.Cicirelli, A. Distante
[dorazio,leo, cicirelli,distante]@ba.issia.cnr.it
*Institute of Intelligent Systems for Automation*
*Via Amendola 122/D-I 70126 Bari (Italy)*

## Abstract

*The problem of eye detection in face images is very important for a large number of applications ranging from face recognition to gaze tracking. In this paper we propose a new algorithm for eyes detection that uses iris geometrical information for determining in the whole image the region candidate to contain an eye, and then the symmetry for selecting the couple of eyes. The novelty of this work is that the algorithm works on complex images without constraints on the background, skin color segmentation and so on. Different experiments, carried out on images of subjects with different eyes colors, some of them wearing glasses, demonstrate the effectiveness and robustness of the proposed algorithm.*

## 1. Introduction

Eye detection is a crucial aspect in many useful applications ranging from face recognition/detection to human computer interface, driver behavior analysis, or compression techniques like MPEG4. By locating the position of the eyes, the gaze can be determined. In this way it is possible to know where people are looking at and understand the behaviors in order to evaluate the interests (for interface purposes) and the attention levels ( for safety controls).

A large number of works have been published in the last decade on this subject. Generally the detection of eyes consists of two steps: locating face to extract eye regions and then eye detection from eye window.

The face detection problem has been faced up with different approaches: neural network, principal components, independent components, skin color based methods [2,11]. Each of them imposes some constraints: frontal view, expressionless images, limited variations of light conditions, hairstyle dependence, uniform background, and so on. A very exhaustive review has been presented in [10].

On the other side many works for eye or iris detection assume either that eye windows have been extracted or rough face regions have been already located [1,3,4,5,6,7,8].

A careful analysis of the related works suggests some considerations: first of all, the problem of face segmentation, distinguishing faces from a cluttered background, is usually avoided by imaging faces against a uniform background. Second, the common use of skin color information to segment the face region is basically based on cumbersome initializations. Finally, more precise is the location of the eye regions, more reliable are the results of the eye detection algorithms.

No much works have been presented in literature that search directly eyes in whole images, except for active techniques: they exploit the spectral properties of pupil under near IR illumination. In [9] two near infrared multiplexed light sources synchronized with the camera frame rate have been used to generate bright and dark pupil images. Pupils can be detected by using a simple threshold on the difference between the dark and the bright pupil images.

The main objectives of our work is to propose an eyes detection algorithm that is applicable in real time with a standard camera, in a real context such as people driving a car (then with a complex background), and skipping the first segmentation step to extract the face region as commonly done in literature.

Our eye detection algorithm works on the whole image, looking for regions that have the geometrical configuration of the edges as the expected ones of the iris. Different iris radius are allowed in order to face with people having different eyes dimensions and also light variations in the distance between the camera and the person. The search of similar regions has been used to discard out false positives that can occur in the image. A large number of tests have been carried out on different people, with different eyes colors and dimensions, some of them wearing glasses. The results are surprising good also considering that no constraint has been imposed on the hairstyle and the background.

The rest of the paper is organized as follows: Section 2 describes the iris detection algorithm in details. Section 3 describes the search of similar regions in order to identify the couple of eyes. The results on different real images are reported in Section 4. Finally, in Section 5 conclusions and future works are presented.

0-7695-2128-2/04 $20.00 (C) 2004 IEEE

## 2. Iris detection

The idea behind our work is quite simple: the eyes can be easily located in the image since the iris is always darker than the sclera no matter what color it is. In this way the edge of the iris is relatively easy to detect as the set of points that are disposed on a circle. It is not possible to know the exact diameter of the iris since people can have different iris dimensions and also the system has to manage variable distances between people and the camera. For this reason a range $[R_{min}, R_{max}]$ is set to tackle different iris radius.

In this work we have used a new circle detection operator that is based on the directional Circle Hough Transform. In particular our algorithm is based on convolutions applied to the edge image. The masks shown in figure 1 represent in each point the direction of the radial vector scaled by the distance from the center in a ring with minimum radius $R_{min}$, and maximum radius $R_{max}$. The convolution between the gradient images and these masks evaluates how many points in the image have the gradient direction concordant with the gradient direction of a range of circles. The maximal value of the convolution result gives the candidate center of the circle in the image.

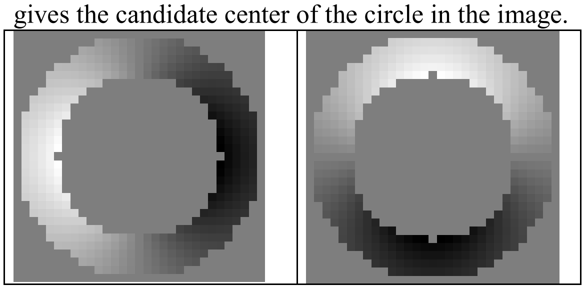

**Figure 1.** The masks of dimension $(2 \cdot R_{max}+1) \times (2 \cdot R_{max}+1)$ that are convoluted with the gradient image.

The circle detection operator is applied on the whole image without any constraint on plain background or limitations on eye regions. The result of this step is a maximum that represents the region of the whole image that is best candidate to contain an eye. In the next section the second step of the algorithm, that searches for a region similar to considered one, is described.

## 3. Search of similar regions

Once the first maximum has been obtained the region candidate to contain one of the eyes is selected. Starting from this area the search of the second eye is applied only in the two opposite regions whose distances and orientations are compatible with the range of possible eyes positions. Let be $(x_1, y_1)$ the coordinate of the central point of the first maximum obtained. The second point $(x_2, y_2)$, where the second eyes could be found, belongs to the regions defined as follow:

$$x_2 = x_1 \pm D \qquad D \in [d_1, d_2]$$

$$y_2 = \tan\alpha \cdot (x_2 - x_1) + y_1 \qquad \alpha \in \left[-\frac{\pi}{6}, \frac{\pi}{6}\right]$$

In this way false positives that occur in the hair regions or on other face parts (such as nose, mouth, and so on) are easily discarded out. Different similarity measures have been explored. The results obtained are quite similar; for this reason, since our main goal is to have frame rate performances, we have decided to choose the one that requires the less computational load. The similarity of the two regions has been evaluated using the Mean Absolute Error (MAE) applied on specular domains:

$$MAE_s = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}\left|a_{ij} - b_{i(M-j+1)}\right|}{N \cdot M}$$

where $a$ and $b$ represent the points in the two regions whose dimensions are $NxM$. The mirroring of the second region is necessary to evaluate the symmetry of the couple of candidate eyes. If this measure of similarity is below a fixed threshold value the two regions are considered the best match for eye candidate, otherwise a further search is activated. The whole procedure used for searching the eyes in the image is described in figure 2.

| |
|---|
| 1. Search the maximum value M1 of the output convolution in the whole image |
| 2. Search the second maximum M2 in the regions that are candidate to contain the second eye |
| 3. Compare the two region M1 and M2 using the measure $MAE_S$ |
| 4. IF ($MAE_S$(M1,M2) < Threshold )<br>THEN<br>Output= M1,M2<br>ELSE<br>M1=0<br>GO TO step 1 |

**Figure 2.** The procedure for searching the second eye.

The results of the similarity measure are of course strictly dependent on the region dimension: smaller are the regions, higher are the false positives found. Intuitively, two similar circular regions can be found in many areas of face images: among curly hair, at the sides of the mouth, on the forehead, and so on. However if the couples of regions considered for the similarity measure are larger than the circular shape searched in the first step, the probability to found false matches decreases. If misdetections happen, they have to be found in symmetric parts of the face.

The experiments show that the similarity constraint is very selective: a large number of wrong candidates are discarded since their similarities overcome the fixed threshold. The threshold has been selected experimentally by evaluating the similarity of a priori known eye regions.

## 4. Experimental Results

In this section the experimental results obtained on a large number of images are shown. Six different persons have been used to take images with different eyes colors, different dimensions and different shapes, for a total of 1423 images. In this work we assumed that the distance between the camera and the person cannot greatly change (people remain sit down on a chair in front of a camera), even if we have considered that people are allowed to slightly move on the chair as it is normally the case. The images taken in these conditions show that the iris dimensions can vary in a range of [20,30] pixels. In figure 3 the images of six persons used in this experiments are shown. No constraints have been imposed on the background.

**Figure 3.** The images of the six persons used in the experiments.

The images have been divided in two sets: eyes completely open and eyes partially visible (in the last set we have considered all the images where people are locking off the center, or the eyelids cover part of the iris). In table 1 the results obtained with the our algorithm are shown.

**Table 1**
Results obtained after the first step.

| | Eyes Open | Eyes partially open |
|---|---|---|
| Person 1 (75) | 73/73 | 1 /2 |
| Person 2 (216) | 212/212 | 3 /4 |
| Person 3 (424) | 390/414 | 6/10 |
| Person 4 (341) | 286/302 | 17/39 |
| Person 5 (249) | 235/235 | 14/14 |
| Person 6 (118) | 93/96 | 0/22 |
| **Detection Rate** | **96%** | **45%** |

The detection rate when the eyes are open is very high. Also when the eyes are partially open the algorithm detects the eyes in about half of the images. It should be considered that at this point no tracking has been implemented and the search of the eye regions is carried out in the whole image. The results will certainly improve if the search will be limited only in predicted areas of the image, especially for the eyes partially visible as in the case of people locking off the center gaze direction.

**Figure 4.** Two of the images of persons wearing glasses

**Figure 5.** Some images with eyes detected correctly

In figures 4 and 5 some results of correct detection are shown; in particular figure 4 shown the eye detection on two images of people wearing glasses. Some correct detection on images taken in real outdoor environment with people driving a car are shown in figure 6.

0-7695-2128-2/04 $20.00 (C) 2004 IEEE

**Figure 6.** Some images with eyes detected correctly

The software has been implemented by using Visual C++ on a Pentium III 1Ghz without any image preprocessing specialized hardware. A Firewire Sony Camera with a frame rate of 7.5 fps and with a focal length of 6.5 mm has been used to take the images. Although no code optimization has been implemented the processing time seems encouraging: the search of the eyes in an image of 640x480 takes quite 0.3 sec. A tracking procedure could be used to reduce the search time in a sequence of images, once the eyes have been correctly detected. Besides, the introduction of code optimization and specialized hardware for convolutions will easily produce real time performances for standard camera frame rate.

## 5. Conclusions and Future Works

In this paper we present an effective algorithm for eyes detection in face images. It consists in two steps: first the region candidate to contain one eyes is detected in the whole image matching the edge directions with an edge template of the iris. Then, the search of the second eye is applied in the opposite regions whose distance and orientations are compatible with the range of possible eyes positions. Our system does not impose any constraint on the background and does not require any preprocessing step for face segmentation.

Tests have been carried out on 1423 images of 6 people; with different eyes color, some of them wearing glasses. High detection rates have been obtained. The results are surprising good also when the eyes are not completely open.

Future work will be addressed to add the eyes recognition ability to our system: indeed in our experiments we supposed that the face images contain always eyes, even if not necessarily completely open. In order to manage more complex situations, such as eyes blinking or head rotations, the further step of eyes recognition is necessary to detect the false positives produced by our system.

## 6. References


[1] T. Kawaguchi, M. Rizon *Iris detection using intensity and edge information,* Pattern Recognition 36 (2003) 549-562

[2] H. A. Rowley, S. Baluja, T. Kanade *Neural Network-Based Face Detection* IEEE Transaction on Pattern Analysis and Machine Intelligence Vol. 20,No. 1, January 1998, pp 23-38

[3] Y. Li, Xiang-lin Qi, Yun-jiu Wang, *Eye detection by using fuzzy template matching and feature-parameter based judgement* Pattern Recognition Letters 22 (2001) 1111-1124

[5] S. Baskan, M. Bulut, V. Atalay *Projection based method for segmentation of human face and its evaluation* Pattern Recognition Letters 23 (2002) 1623-1629

[6] S. Sirohey, A. Rosenfiled *Eye detection in a face image using linear and nonlinear filters* Pattern Recognition 34 (2001) 1367-1391

[7] S. Sirohey, A. Rosenfiled, Z. Duric *A method of detection and tracking iris and eyelids in video* Pattern Recognition 35 (2002) 1389-1401

[8] M. Rizon, T. Kawaguchi *Automatic extraction of iris with reflection using intensity information* Proceeding of the 3th Iasted Conference on Visualization Imaging and image processing September 8-10, 2003 Benalmaden Spain

[9] P. Smith, M Shah, N. da Vitoria Lobo, *Determining Driver Visual Attention with One Camera*, Accepted for IEEE Transactions on Intelligent Transportation Systems.

[10] C.H. Morimoto, D. Koons, A. Amir, M. Flickner *Pupil detection and tracking using multiple light sources* Image and Vision Computing 18, (2000) 331-335

[12] M. H. Yang, D. Kriegman, N. Ahuja *Detecting Faces in Images: A Survey* IEEE Transaction on Pattern Analysis and Machine Intelligence Vol. 24, No. 1 January 2002

[13] R. Hsu, M. Mottleb, A. K. Jain *Face Detection in Color Images* IEEE Transaction on Pattern Anlysis and Machine Intelligence Vol24, No. 5, May 2002