Active Contour and Morphological Filters for Geometrical Normalization of Human Face

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Abstract. In this paper we resolve the problem of automatically normalize front view photos from a database that contain images of human faces with different size, angle and position. It was used a template with a standardized inter eye distance and dimensions. We are mapping all images to this template applying a geometrical transformation. It is necessary to obtain the eyes positions on image to calculate the transforms parameters. That is not a trivial problem. We use active contour to detect the human face. After that, we apply morphological filters to highlight image signal amplitude in the eyes positions. A set of criterion is applied to select a pair of point with more possibility to be the eyes. Then, a subroutine is feed with eyes coordinates to calculate and apply the geometrical transformation. Our method was applied to 500 photos and it performs very well in the 94% of all cases.

1 Introduction

Face recognition [1, 2, 3, 5] has become an important issue in many applications such as access control, credit card verification and criminal identification. The main task of face recognition is the identification of a given face photo among all the faces stored in an image database. This is our general problem. Our approach need to known the position of eyes to create a face space in which all the faces are geometrically normalized and photometrical correlated [4, 8].

This paper is dedicated to the process of geometrical normalization of human faces. This process is divided in three steps: a) face detection, b) eye detection and c) geometrical normalization [6, 11, 12].

First, it is necessary localize the limit of face using active contour [9, 10]. Then, the eyes are detected searching white spot in a map resulting of apply a combination of morphological filters. Finally, it is performed the geometrical normalization.

The structure of this paper is the following: In section 2, we show the basic concepts about active contour and its employ in face detection. The face and eye detection process are presented in Section 3 and 4 respectively. Section 5 is dedicated to explain the spatial transformation. Section 6 focuses on experimental results of the proposed methodology. Finally, we present some relevant conclusions.

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2 Active Contour Model (Snake)

The active contour or snake can be defined as a spline curve that minimize the energy guided by external constraint forces and influenced by image forces that pull it toward feature as lines and edges. In the snake, image and external forces together with the connectivity of contour and the presence of corners will affect the energy function and the detailed structure of the locally optimal contour. The snake has a set of inner forces that serve to put smoothing restrictions to the curve. Also, it has a set of image forces and restrictions imposed by the user. The idea, it is modify an initial elastic curve under the action of such forces until reach the object contour.

The definition of the active energy of the contour is illustrated as

$$E_{snake} = \int_0^1 \alpha E_{\text{int}\,ernal}(r(s)) + \beta E_{image}(r(s)) + \delta E_{\text{restrictive}}(r(s))ds \,. \quad (1)$$

Where $r(s)$ represent the position of the snake, $E_{\text{int}\,ernal}$ represents the internal energy of the contour due to bending. Defined as

$$E_{\text{int}\,ernal}(r(s)) = \|r'(s)\|^2 + \|r''(s)\|^2 \,. \quad (2)$$

The following approximations are used:

$$\left\|\frac{dr_s}{ds}\right\| \approx \|r_s - r_{s-1}\|^2 \quad \text{and} \quad \left\|\frac{d^2 r_s}{ds^2}\right\| \approx \|r_{s-1} - 2r_s + r_{s+1}\|^2 \,. \quad (3)$$

Continuity Force: The first derivative $\|r_s - r_{s-1}\|^2$ causes the curve to shrink. It is actually the distance between points. It is evident that a term that facilitates the uniform distribution of the points $d_{pro} - \|r_s - r_{s-1}\|^2$ would much more reflect the wished behavior of contour.

Curvature Force: Since the formulation of the continuity term causes the points to be relatively evenly spaced, $\|r_{s-1} - 2r_s + r_{i+1}\|^2$ gives a reasonable and quick estimate of

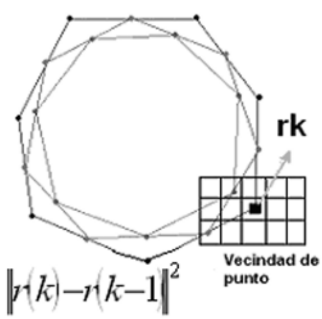

Fig. 1. Continuity forces: Minimizing the distance between points

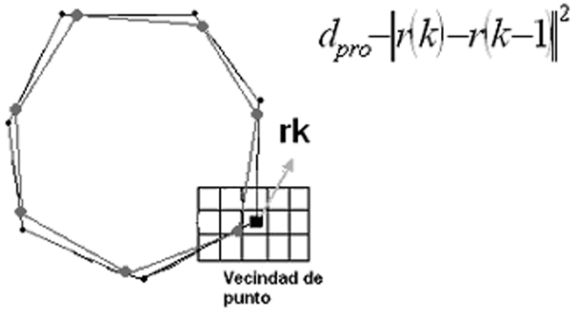

Fig. 2. Continuity forces: Minimizing the difference between the average distance points d_{pro} and the distance between the two points under consideration

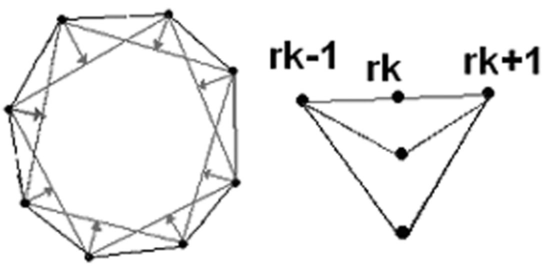

Fig. 3. Curvature Force

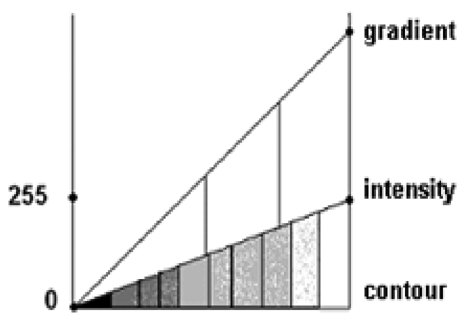

Fig. 4. Image force

the curvature. This term, like the continuity term, is normalized by dividing the largest $d_{\max}$ value in the neighborhood, giving a number between 0 and 1.

Image Force: E_{image} is the image force which is defined taking account the intensity in a point and the gradient of the intensity in a point. We need to select a point in the neighborhood which intensity plus gradient minimize the energy function. When the contour is white it is necessary multiply by -1 this value.

Restrictive Force: It is the distance between an inner points and other on the contour. As the criterion considered is to minimize the energy, the curve will be shrinking. In the case that we are interested to expand the curve, it is necessary to consider multiply by -1 the distance.

3 Face Detection

The basic idea is close a face in a frame to minimize the negative effect of the hair to the algorithm of facial feature extraction. We may initialize a process of expansion of an inner curve searching the face contour applying the snake principle. The problem is to be sure that the initial set of point is internal to the face. To guarantee this condition, it is possibly to apply an active contour to shrink a curve in form of an ellipse to reach the external edges of hair and face. A Sobel filter is applied to the image to facilitate the convergence of snake to the searching edges (see Fig. 5). This way, it is found a previous face approximation closed in a rectangle.

As the snake finish its iterations, it is obtained a set of point most of them over the head contour. Then, a searching is initiated to look up for the two rows and columns with more density of point to form a frame including the face (see Fig. 6).

We position a set of point in the centre of this rectangle to begin a second expanding snake. Initial snake into the face is not a sufficient condition for all points evolve to the

Fig. 5. a) Face image. b) Sobel edges detection.

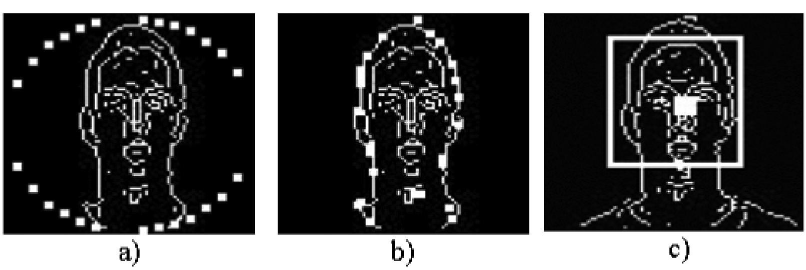

Fig. 6. Shrinking snake evolution. a) Initial elliptical curve, b) Points over the contour, and c) Frame including the face.

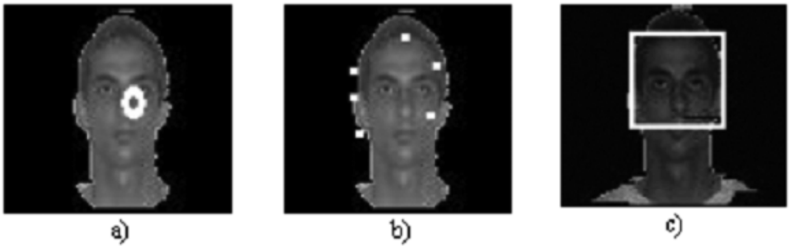

Fig. 7. Expanding snake evolution. a) Initial elliptical curve, b) Points over face contour, and c) Frame including the face.

face contour because some points may be trapped on the eyebrow, eyes and nostril. Only the points over the face contour were taken to build the inner frame (see Fig. 7).

4 Eye Detection

We are interested in highlight the eyes location and eliminate other image elements. Based in the observation that eye images have a combination of white and black pixels, we proposed to utilize dilation filter to amplify the whites pixels and erosion filter to amplify the black one. Then, it is possibly to obtain a map of shade value (*Map*) where the eyes locations are highlighted. This map is obtained by the

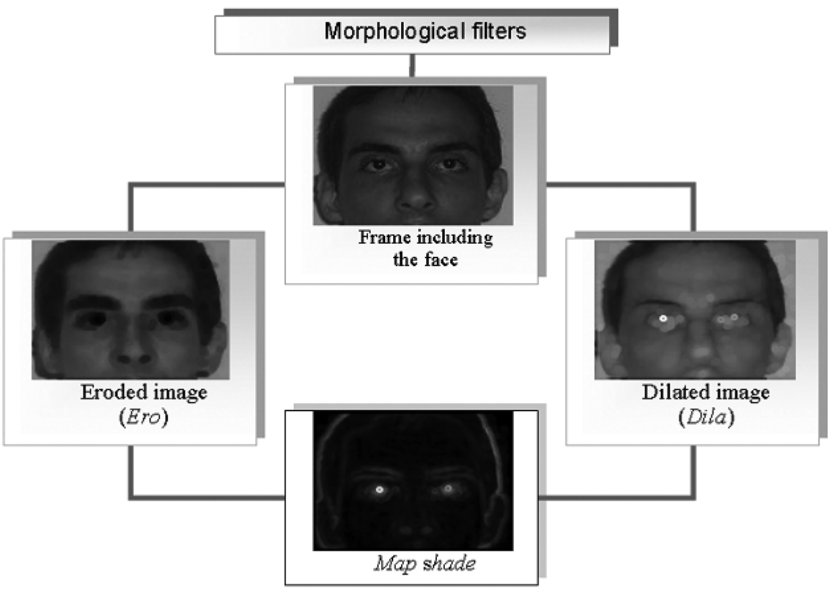

Fig. 8. Morphological operation to obtain the Map shade

Fig. 9. Map shade dilated

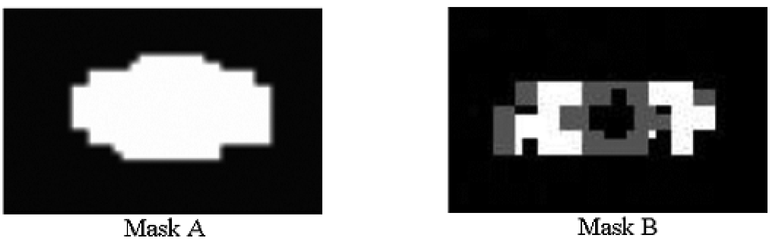

Fig. 10. Masks used to detect eyes positions

subtraction of image dilated (*Dila*) minus image eroded (*Ero*). With this operation we pretend to remark the difference between pixels black and white in both images (see Fig. 8).

$$Map = Dila - Ero \ . \tag{4}$$

After that, a dilate operation is applied to the Map shade to highlight image signal amplitude in the eye position.

On the shade map we select the 10 positions that obtain greater value when matching with Mask A. These points are evaluated in the original image by means of Mask B. The pair of greater score is chosen as the eyes, where the horizontal orientation and the distance between the possible points associated to eyes fulfill the correspondent thresholds.

5 Geometric Normalization

A geometric transformation consists of a spatial transformation, which defines the arrangement of pixels on the image planes and the gray level interpolation, which deals with the assignment of gray levels to pixels in the spatially transformed image. We defined a template with 500 x 400 pixels and the exactly location where is desire to put the eyes of all transformed images (see Fig. 11). This point on the template and the eyes locations are using as *tiepoints*. We used gray level interpolation based on the nearest neighbor concept.

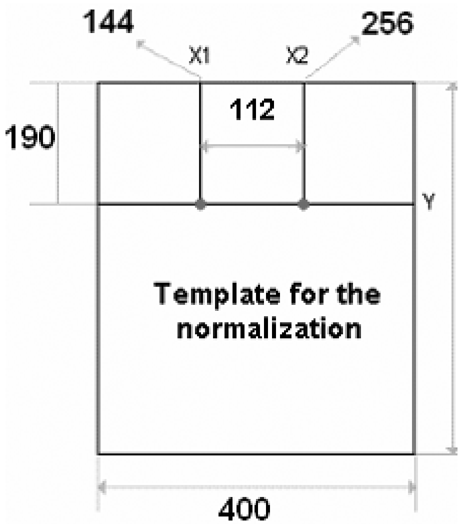

Fig. 11. Template used for the geometric normalization. Left eye (144,190) and right (256,190).

6 Result

In this section, we show some results obtained with our methodology. We selected 500 front view images of students and professors from Havana University, where appear persons with different ages, sex, length of hair, color of skin, head inclination, illumination, color and scale (see Fig. 12 left).

The eyes were correctly detected in 94 percent of images with a probability of more than 9 positive results into 10 images (see Fig. 12 right). Figure 13 show some human faces normalized using the automatic detected coordinates of eyes.

We observed some negative results where the snake does not work very well and the algorithm was affected by earring and glasses with much shine.

7 Conclusions

We present a new methodology for eyes detection that combines active contour, morphological filters and template matching.

We introduce an additional restrictive force in energy function to obligate the snake to evolve to the wanted contour.

We obtained a 94 percent of effectivity when the algorithm was applied to 500 images of faces took in conditions not controlled, corresponding to students of Havana University.

The algorithm presented in this paper resolve the problem of normalization of a set of images mapping all them over a template with standard spatial dimensions, without necessity of manually marking the eyes position.

Fig. 12. Some of the photos of the registry. Left: Original photos. Right: Eyes detected.

Fig. 13. Examples of normalized images

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