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A New Approach for Face Recognition Based on Iris Detection

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ABSTRACT

I propose a system to identify the unknown person in a face image for which the position, scale and image-plane rotation of the face are unknown. The proposed system detects the iris of both eyes and normalizes the position, scale and image-plane rotation of the face using iris positions. The algorithm measures the degree of matching betlen the image and the face template of each person using normalized cross-correlation value. Recognition of a person is done using the highest degree of matching. The execution time of the recognition is 0.66 [seconds] with Pentium IV, 2.8GHz.

Keywords: *face recognition, iris detection, template matching, computer vision.*

INTRODUCTION

Computer recognition of human faces has many applications such as security systems, mug shot matching and model-based video coding. There are two approaches for face recognition: template based approach [1], [3] and feature based [1], [4].

The first approach identifies the unknown person in an image by matching the image face to the templates of reference faces stored in the database. The second approach identifies the unknown person in an image by using geometrical measurements of facial features. The approach requires the detection of facial features such as eyes, eyebrows, nose and mouth. Holver, the correct detection of facial features is difficult except for the restricted cases. In addition, [1] reported an experimental result showing that the first approach was superior to the second approach.

In this paper, I propose a template-based face recognition system. The proposed system can be applied to a face image in which the position, scale and image-plane rotation of the face are unknown. The proposed system first detects the irises of both eyes and then normalizes the position, scale and image-plane rotation of the face using the positions of the irises of both eyes.

The iris is a darker region than its surrounding and the shape of the iris is a circle. Using these properties of the iris, the proposed system measures the iris-likeness of each blob. In addition, the proposed system measures the iris-likeness of each blob-pair using a template of both eyes obtained by cutting off the region of both eyes from a face image.

METHODOLOGY

The proposed face recognition system

I assume the followings about the input image.

(1) The image is an intensity image.

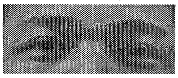
(2) The image is a head-shoulder image with plain background and the face in the image is a frontal face.

(3) The size and the image-plane rotation of the face in the image are unknown although their lolr bounds and upper bounds are given in advance.

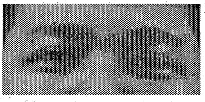
(4) The irises of both eyes appear in the image.

Below, I show the face recognition system proposed in this paper.

For each person, I prepare an intensity image of his frontal face and cut off a region consisting of both eyes and eyebrows from the image (see Figure.1). The region is called the face template of the person and is denoted by $T(u, v)$, $0 \leqq u \leqq m-1$ and $0 \leqq v \leqq n-1$. I prepare another template $T_E(u, v)$, $-p \leqq u \leqq m-1+p$ and $-p \leqq v \leqq n-1+p$, for each person. (p was set to 10). The template T_E is called the extended template. The reason why I use the extended template for each person will be shown later.



face template



extended template

Figure.1 The face template and the extended template

Figure 2: The positions of the irises of both eyes detected by the iris detection algorithm from input image.

Face recognition stage

(1) Extract the irises of both eyes of the unknown person in the input image using the algorithm shown in the next section. Let (x_1, y_1) and (x_2, y_2) denote the positions of the irises of the left and right eyes (see Figure.2).

(2) For each person in the database, do the following sub steps (2-1) to (2-4).

(2-1) Let (u_1, v_1) and (u_2, v_2) denote the positions of the irises of the left and right eyes in the face template of the current person. Then, apply an affine transform to the input image so that the positions of the irises (x_1, y_1) and (x_2, y_2) in the input image have the coordinates (u_1, v_1) and (u_2, v_2) in the new image.

(2-2) Let $T_E(u, v)$, $-p \leqq u \leqq m-1+p$ and $-p \leqq v \leqq n-1+p$, denote the extended template of the current person. Then, cut off a window W (u, v), $-p \leqq u \leqq m-1+p$ and $-p \leqq v \leqq n-1+p$, from the input image after transformation.

(2-3) Moving the face template T over the window W, compute the normalized cross-correlation value C by

$$C = \frac{E(TW_T) - E(T)E(W_T)}{\sigma(T)\sigma(W_T)} \tag{1}$$

W_T denotes a patch of W matched to T. E(T) and ó(T) are the average and the standard deviation of the intensities of pixels inside T. $E(W_T)$ and ó(W_T) are similarly defined. $E(TW_T)$ denotes the average of the pixels-by-pixel products of T and W_T.

(2-4) Find the maximum value of C over all pixels inside W and let the maximum value of C denote the degree of match betlen the current person and the input image.

(3) Find a person that has the best match to the input image. I determine this person to be the unknown person in the image.

The maximum of C is not always obtained when the template is placed on the image so that the iris positions of the template coincide with the iris positions of the image. Therefore, the proposed algorithm cuts off a slightly larger window than the face template from the image and moves the template over the window to detect the position of the template maximizing C. To cut off a slightly larger window than the face template from the image, the proposed algorithm prepares the extended template for each person in addition to the face template.

Detection Of The Irises

As shown in the last section, the face recognition system proposed in this paper uses the positions of the irises of both eyes to normalize the position, scale and image-plane rotation of the face in the image. In this section I show the iris detection algorithm used in our face recognition system.

The proposed iris detection algorithm first extracts the head region from the image and then extracts the candidates for the irises, called blobs, from the head region using the algorithm of [6] and the algorithm of [7]. Next, using a procedure proposed in this paper, the algorithm computes a cost for each pair of blobs satisfying a spatial constraint. Finally, the algorithm determines a pair of blobs with the smallest cost to be the irises of both eyes. Below, I show the details of the proposed iris detection algorithm.

Extraction of the head region

First, I apply the Sobel edge detector to the original intensity image $I(x, y)$, $0 \leqq x \leqq M-1$ and $0 \leqq y \leqq N-1$. Let $E(x, y)$ denote the obtained edge image where $E(x, y)=1$ if (x, y) is an edge pixel and otherwise $E(x, y)=0$.

Next for each column x and each row y, V(x) and H(y) are computed by

$$V(x) = \sum_{y=0}^{N-1} E(x, y), \quad H(y) = \sum_{x=0}^{M-1} E(x, y) \tag{2}$$

The x-positions x_L and x_R of the left and right boundaries of the head are given by the smallest and largest values of x such that $V(x) \geqq V(x_0)/3$ where x_0 denotes the column x with the largest V(x). And, the y-position y_{min} of the upper boundary of the head is given by the smallest y such that $H(y) \geqq 0.05(x_R - x_L)$. Finally, I give the y-position y_{max} of the lower boundary of the head by $y_{max} = y_{min} + 1.2(x_R - x_L)$.

Although the head contours obtained by the above procedure are not exact, the irises of both eyes are surely included in the obtained face region.

Detection of iris candidates

I first give a brief description of the algorithm proposed by Lin and Wu [6] to detect iris candidate center. The algorithm extracts the face region from the input image using a region-growing method. Next, for each pixel (x,y) inside the face region, the algorithm computes a cost C(x, y) by

$$C(x,y) = C_1(x,y) + C_2(x,y) \tag{3}$$

Let S(x,y) denote the square region with center (x,y) and side-length d. Then, $C_1(x,y)$ is given by

$$C_1(x, y) = \sum_{j=y-d/2}^{y+d/2} V_r(j) + \sum_{i=x-d/2}^{x+d/2} V_c(i) \tag{4}$$

$V_r(j)$ and $V_c(i)$ are the mean crossing numbers of row j and column i which are defined as follows.

Let $I(i, j)$ denote the intensity values of pixels (i, j) in the image. Then, for each row j, $V_r(j)$ represents the number of pixels (i, j), $x - d/2 \leqq i \leqq x + d/2$, such that one of the $I(i-1,j)$ and $I(i,j)$ is greater than μ plus K and the other is smaller than μ minus K where μ is the average intensity of pixels (i, j), $x - d/2 \leqq i \leqq x + d/2$ and K is a constant. $V_c(i)$ denotes the number of pixels (i, j), $y - d/2 \leqq j \leqq y + d/2$, such that one of the $I(i, j-1)$ and $I(i, j)$ is greater than μ plus K and the other is smaller than μ minus K. $C_2(x, y)$ is a function which evaluates the intensity difference between the central part and the boundary parts of $S(x, y)$

After partitioning the face region into the left eye subregion, the right eye subregion and the mouth subregion, the algorithm selects three pixels with the largest costs, one from each subregion, and determines these pixels to be the positions of the left eye, the right eye and the mouth.

The feature template used in the algorithm of [6] is very attractive because it is robust even when some subregions of the face exhibit low contrast. But, I verified by our experiments that although the costs of facial feature points are relatively large, the probability that a facial feature point has the largest cost inside each sub region is low. Thus, the eye detection algorithm proposed in this paper uses the algorithm of [6] to detect candidates for both eyes. In this paper, feature points mean the centers of iris candidates.

After extracting the valley region from the face region, the proposed algorithm computes costs C(x,y) for all pixels (x,y) inside the valley region using the feature template proposed by [6]. The costs are given by Eq.(3). Next, as feature points, the proposed algorithms selects pixels (x,y) that give the local maxima of C(x,y).

In the proposed iris detection algorithm, the irises are modeled by circles. Let (x,y) and r denotes the centers and the radii of the irises modeled by circles.

According to [7], the separability ç between regions R_1 and R_2 of the eye template is given by

$$\eta = \frac{B}{A} \tag{5}$$

$$A = \sum_{i=1}^{N} (P_i - \overline{P}_m)^2$$

$$B = n_1(\overline{P}_1 - \overline{P}_m)^2 + n_2(\overline{P}_2 - \overline{P}_m)^2$$

where

n_k $(k=1,2)$: the number of pixels inside R_k,
$N = n_1 + n_2$,
$\overline{P_k}$ $(k=1,2)$: the average intensity inside R_k,
$\overline{P_m}$:the average intensity inside the union of R_1 and R_2,
P_i :the intensity values of pixels i.

Letç(x, y, r) denote the separability betlen two regions R_1 and R_2 in the template with size r placed at pixel (x, y). As the candidates for the irises, I select triplets (x, y, r) which give the local maxima ofç(x, y, r). The circles defined by these triplets are called blobs in this paper.

Costs of iris candidates

Let $B_i = (x_i,\ y_i,\ r_i)$ denote blobs obtained by the procedure shown in the last section. First, I apply the Canny edge detector [9] to the head region and then measures the fit of blobs to the edge image using the circular Hough transform [10]. I give the equation of a circle by

$$(x-a)^2 + (y-b)^2 = r^2 \tag{6}$$

where (a, b) is the circle center and r is the radius.

Let P denote an edge point lying on the boundary of the circle corresponding to the iris. If P has the position (x, y) and the orientation$\theta$and the error of$\theta$is at most$\Delta\theta$, the center(a, b) of the circle lies on the arc given by $R=\{(a, b)|a=x+r\cos(t), b=y+r\sin(t), +\pi-\Delta\theta \leqq t \leqq \theta+\pi+\Delta\theta\}$. I denote the arc defined above by $(x, y, r, \theta+\pi-\Delta\theta, \theta+\pi+\Delta\theta)$ In the experiments, $\Delta\theta$ was set to 45 [degrees].

First, for each $r \in \{r_i -1, r_i, r_i +1\}$, and for each edge point P inside the square region with center (x_i, y_i) and side-length 2r, enumerating all integer points (a,b) on the arc $(x, y, r, \theta+\pi-\Delta\theta, \theta+\pi+\Delta\theta)$ where (x,y) and$\theta$are the position and the orientation of P, vote for (a, b, r). Next, select (a, b, r) with the largest vote. I denote the largest vote by V(i), which is called the vote for B_i.

Next, I first place the template of Figure.3(a) at the position (x_i, y_i) on I(x, y) and then compute the separabilities η_{23}(i) andη_{24}(i) by using Eq.(5), whereη_{kl}(i) denotes the separability betlen regions R_k and R_l. Similarly, I compute the separabilitiesη_{25}(i) andη_{26}(i) using the template of Figure.3(b).

Finally, the cost of each blob B_i is given as follows.

$$C_b(i) = C_1(i) + C_2(i) + C_3(i) + C_4(i) \tag{7}$$

$$C_1(i) = \frac{V_{max}}{V(i)}, \quad C_2(i) = \frac{|\eta_{23}(i) - \eta_{24}(i)|}{\eta_{23}(i) + \eta_{24}(i)}$$

$$C_3(i) = \frac{|\eta_{25}(i) - \eta_{26}(i)|}{\eta_{25}(i) + \eta_{26}(i)}, \quad C_4(i) = \frac{U(i)}{U_{av}}$$

where

V(i) : the vote for B_i given by Hough transform,
V_{max} : the maximum of V(i) over all blobs,
U(i) : the average intensity inside B_i,
U_{av} : the average of U(i) over all blobs.

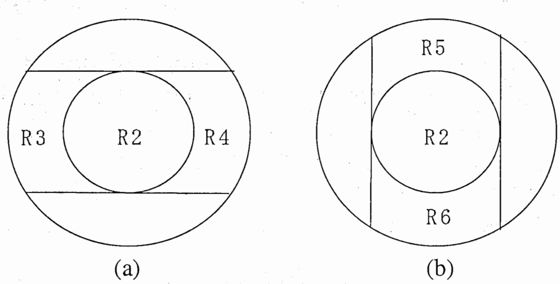


Figure 3 : The templates used to compute C_2(i) and C_3(i)

Iris selection

For each pair of blobs B_i and B_j , let d_{ij} andθ_{ij} denote the length and the orientation of the line connecting the centers of B_i and B_j . The proposed algorithm computes a cost for each pair of blobs B_i and B_j such that $L/4 \leqq d_{ij} \leqq L$ and $-30^\circ \leqq \theta_{ij} \leqq 30^\circ$ where L is the difference betlen the x-positions of the left and right contours of the head. And, a pair of blobs with the smallest cost is determined to be the irises of both eyes

The cost of a blob-pair B_i and B_j is given by

$$F(i,j) = C_b(i) + C_b(j) + 1/R(i,j) \tag{8}$$

where C_b(i) and C_b(j) are the costs computed by Eq.(7) and R(i, j) is the normalized cross-correlation value computed by using an eye template.

For each pair of blobs B_i and B_j, the algorithm computes R(i, j) by using the following procedure.

(1) Apply an affine transform to the input image so that the centers of B_i and B_j are placed at the centers of the irises in the template, respectively.
(2) Compute the normalized cross-correlation value R(i,j) betlen the template and the image by using Eq.(1).
(3) If R(i,j) is smaller than 0.1, then set R(i, j) to 0.1.

EXPERIMENTAL RESULTS

I made experiments using face images of 8 persons to evaluate the performance of the proposed face recognition system.
Face templates and test images Ire produced by the following way.
(1) After taking pictures of 8 persons using a digital video camera (PANASONIC NV-GS70), I selected 80 pictures of near-front faces.
(2) Next, for each person, I selected a face which was nearest to the right front face and then cut off the face template from this face.
The success rate of the proposed system was 97.5%. All failures occurred in face recognition Ire due to failures of the iris detection. I can say from the results of the experiments that the performance of the proposed system is very sensitive to the iris positions.

By experiments, I verified that while the iris positions detected by our algorithms Ire exact if our algorithms could correctly select a pair of iris candidates corresponding to the irises of both eyes, the original template matching [1] and the original eigenspace method [5] could only detect the rough positions of the irises.

The execution time of the proposed system to identify the unknown person in an image was about 0.66 [seconds] on the average by a computer whose CPU was Pentium IV, 2.8GHz.

Table 1 shows the execution time of each step in the proposed system. Figure.4 shows examples of the face images for which the proposed system gave successful results.

Table 1: The execution times for each step of the proposed system

Step	CPU time in seconds
Head region detection	0.01
Valley detection	0.13
Candidate center detection	0.14
Candidate radius detection	0.06
Iris selection	0.15
Cross-correlation computation	0.17
Total	0.66

CONCLUSIONS

I proposed a system to identify the unknown person in a face image for which the position, scale and image-plane rotation of the face are unknown. The proposed system first detects the irises of both eyes and then normalizes the position, scale, image-plane rotation of the face in the image using the positions of the irises of both eyes. After that, the algorithm measures the degree of match betlen the image and the face template of each person using the normalized cross-correlation value and determines a person with the highest degree of match to be the unknown person in the image.

Most of the eye detection algorithms previously reported use template matching, eigenspace method, or Hough transform. Holver, template matching and eigenspace method require the normalization of the image face in its size and orientation when the variations in size and orientation of the image face are not small. And, these algorithms can correctly detect only eye patterns that are similar to sample eye images used as eye models. In addition, eye detection algorithms using Hough transform need to estimate the searching windows for eyes inside the face region because eyes are considerably small as compared to the face size. Thus, these algorithms require a complete face region detection. The eye detection algorithm proposed in this paper only requires a rough estimation of size and orientation of the face in the image.

I made experiments using 80 face images of 8 persons. Each face has roughly the same size as that of the model face. The success rates of the proposed face recognition system was 97.5[%]. The time needed by the proposed system to identify the unknown person in an image was about 0.66 [seconds] on the average by a computer whose CPU was Pentium IV, 2.8GHz. In experiments, the fast system had high success rates. But, comparison of the success rate of our system with those of the previously reported systems is a future work.

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APPENDIX

Examples of the face images for which the proposed system gave successful results