Automatic Detection of Face and Facial Features

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Abstract: - An algorithm to automatically detect facial features from color images has been developed. First, face region is located using skin-color information. Then, the iris candidates are extracted from the intensity valleys created from the detected face. Next, the costs for each pair of iris candidates are computed to determine the real pair of irises. Mouth region and corners are detected using color space method, image processing and corners detection techniques. This algorithm has been tested to specifically reduce the effects of beard, moustache, hairstyle and facial expression in automated facial features detection.

Key-Words: - Face recognition, Iris detection, Mouth detection, Facial features

1 Introduction

In the past ten years, face recognition has attracted substantial attention from various disciplines and seen a tremendous growth in researches. Face recognition has been widely applied in security system, surveillance system, credit card verification and other applications. Automatic face and facial features detection have become important for face recognition. Humans are good at face identification but recognizing human face automatically by computer is never an easy task.

Automated face recognition has been applied in two ways: holistic and feature-based. The holistic approach [3, 4] treats a face as 2-dimensional pattern of intensity variation. Generally, eyes and mouth are important facial landmarks which significantly affect the performance of face recognition. The feature-based approach [2, 13, 14] recognizes a face using the geometrical measurements taken among facial features such as eyes, nose and mouth. Many researches have proposed methods to find the eyes [8], mouth regions [4, 5] or to locate the face region [2, 3, 7] in an image. These methods have shown the popularity of using information such as template matching, geometrical and intensity features. R. Brunelli and T. Poggio [2] and D. J. Beymer [3] located eyes using template matching. However, template matching and eigenspace method require normalization of the face for variation of size and orientation. A large number of templates are needed for template matching to accommodate varying pose.

A popular method used in geometric-feature based approach is the use of vertical and horizontal projections. The projections can be employed on the first derivative of the image [2] or directly on the intensities values. Projection based methods [6, 8] have been used particularly to find coarsely the position of the facial features. Besides, the projection method is being combined with other methods such as template matching, genetic algorithm [7] and the Smallest Univalue Segment Assimilating Nucleus (SUSAN) algorithm [14]. SUSAN algorithm is among the most popular for eyes, nose and mouth corner detection in grayscale images [15, 16]. Combination of this algorithm with image processing and color information to detect facial features has also been done [17, 18, 19].

There are only a few studies that gave qualitative results about the performance of features localization. Most of the sample images used in previous studies [6, 8, 13, 14, 17, 18, 19] did not contain beard or moustache. The aim of this proposed algorithm focuses on reducing the effects of thick beard, moustache, long hair, expressions and genders on facial features detection. The combination of methods to detect eyes and mouth proposed in this algorithm has not been applied in previous studies.

The proposed algorithm will first locate the face region using skin-color information. Then, iris candidates are extracted from valleys based on computed costs. This algorithm will then detect the lips region using the RGB color space. Image processing methods such as opening, closing, filling and dilation are applied. Connected component labeling is being used to eliminate unwanted noise and regions. Finally, SUSAN algorithm is applied to detect the mouth corners in order to obtain the accurate position of mouth.

2 Face Localization

In order to achieve the objectives of this experiment, color images from both genders with beard, moustache, long hair and facial expressions are specifically chosen from the online face database [20]. The images are assumed to be head-shoulder images with plain background and head rotation on y-axis is approximately within the interval ± 30 degrees. The proposed algorithm first creates a skin-color model for the face region detection from color images.

$$r = \frac{R}{R+G+B}, \ g = \frac{G}{R+G+B} \qquad (1)$$

Using the rg color space, a skin-color model [19] is created. First, Select skin-color pixels (x, y) whose color value $v = (r, g)$ satisfies $g(v) \ge \varepsilon$ (The threshold value for this experiment is 0.05). Second, estimate the mean and covariance matrix of the pixels in the selected regions. Then, the Gaussian distribution model is computed using the probability density function. Mathematical morphology: opening and closing are applied to the region of skin-color pixels. Finally, the largest area of connected component of the region is defined as face region.

3 Iris detection

The proposed algorithm will first convert the color image to grayscale image and applies grayscale closing [12] to the face region to extract valleys. $V(x, y) = G(x, y) - I(x, y)$ where $G(x, y)$ and $I(x, y)$ denote its intensity value and value obtained by applying grayscale closing. Then, region consisting of pixels (x, y) such that $V(x, y)$ is greater than or equal to a threshold value are determined to be valleys. Preprocessing steps such as histogram equalization and light spot deletion are performed to enhance the quality of image and reduce illumination effect in this algorithm.

3.1 Selection of iris candidates

In irises selection, this algorithm performs the similar method as proposed by Tsuyoshi Kawaguchi and Mohamed Rizon [1]. First, it computes the costs $C(x, y)$ for all pixels in the valleys and selects m pixels according to non-increasing order that give the local maxima of $C(x, y)$.

$$C(x, y) = C_1(x, y) + C_2(x, y) \qquad (2)$$

Place the eye template as shown in [1] at each candidate location and measures the separability [10] between two regions R_1 and R_2 given by:

$$\eta = \frac{B}{A} \qquad (3)$$

Next, it applies Canny edge detector [11] to the face region and measures the fitness of iris candidates to the edge image using Hough transform [21]. Given an iris candidate $B_i = (x_i, y_i, r_i)$, measures the fitness of iris candidates to the intensity image by placing two templates as shown in Fig. 1. Compute the separabilities $\eta_{23}(i)$, $\eta_{24}(i)$, $\eta_{25}(i)$ and $\eta_{26}(i)$ using Eq. (3).
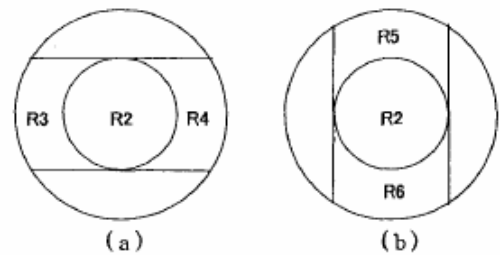

Fig. 1: The templates used to compute $C_2(i)$ and $C_3(i)$

Then the cost for each iris candidate is calculated as below:

$$C(i) = C_1(i) + C_2(i) + C_3(i) + C_4(i) \qquad (4)$$

Finally, computes the cost for each pair of iris candidates B_i and B_j:

$$F(i, j) = t\{C(i) + C(j)\} + (1-t)/R(i, j) \qquad (5)$$

where $C(i)$ and $C(j)$ are costs computed by Eq. (4). $R(i, j)$ is the normalized cross-correlation value computed by using eye template which is produced by manually cut from a face image. t is the weight to adjust two terms of the cost. The lowest cost, $F(i, j)$ is selected as the pair of irises as shown in Fig. 2.

Fig. 2: Result for iris detection

4 Mouth region and corners detection

First, the algorithm uses the detected irises location as the left X_l and right X_r boundaries in estimating mouth region. Then, the vertical positions of both irises are used to obtain a mean value, Y_{min}.

$$Y_1 = Y_{min} + (X_l - X_r) \times R$$
$$Y_2 = Y_1 + H \qquad (6)$$

where Y_1 and Y_2 are the upper and lower boundaries, R is the height ratio and H is the height of the estimated mouth region. The region of interest with the calculated width and height from Eq. (6) is being clipped out of the original color image. RGB color space similar to Eq. (1) is being applied to the clipped image. The red component is compared with the green and blue in RGB color space with a threshold being set.

$$I1 = ((R/R + G + B) > threshold*(G/R + G + B) = 1)$$
$$I2 = ((R/R + G + B) > threshold*(B/R + G + B) = 1)$$
$$I = I1 * I2 \qquad (7)$$

where I is the detected white region.

Connected component labeling plays an important role to get the mouth region. In this case, the mouth region with moustache and beard will have larger connected component. If the area of the connected component exceeds a threshold, opening

and closing of the mathematical morphology have to be applied. If it is below the threshold, only closing morphology is needed. Dilation morphology is being added for the case of female to obtain a more complete region. In certain cases, median filter is being used to eliminate noises. After applying all these image processing methods, the largest member of the connected component is chosen as lips region.

SUSAN corner detector is then applied on the image as shown in Fig. 3. Corners will be detected at the boundary of the white region. The two corners located at the left most and right most are determined as mouth corners. When there is more than one corner with the same x-position at each side, the point with the nearest y-position to the middle of the image will be chosen as corner. The error rate can be reduced by final adjustment of the mouth corners' positions. Average of y-coordinates form both sides can help in minimizing the error. This can be very useful when there is only one failure corner detection with small deviation at either side.

Fig. 3: Mouth region of interest after image processing.

5 Results and discussion

Experiments have been arranged to evaluate the performance of the proposed algorithm. There are 72 color images from AR face database [20] which have been chosen. The size of each image is 768×576. There are 12 subjects for male and female. These images chosen can cover variety of poses, head orientations and different face contours. A large number of these images are with beard, moustache, long hair and facial expressions. The proposed algorithm aims to reduce the effects of such stated conditions which have already affected the detection rate of facial features as well as face recognition decades ago.

Table 1: Successful detection rate for iris and mouth corners.

AR Face Database	Detection Rate of Facial Features (%)	
	Iris	Mouth corners
Male	94.44	97.22
Female	91.67	94.44
Overall	93.06	95.83

Table 2: Processing time for iris and mouth detections.

Facial Features Detection	Processing time (seconds/image)
Iris	2.04
Mouth	0.46
Total	2.50

The experiment has been done on male and female to analyze the impact of gender on face recognition system. This is not a large face database but the variety of faces and different types of subjects are more than adequate to test the robustness of this algorithm. From Table 1, the overall performance of this algorithm in iris detection has achieved 93.06% success rate. We can observe a slightly lower detection rate in female case caused by the color and intensity of female's irises. When the color of the iris is blue, the intensity difference between iris and outer region is lower. This may result in failure cases where only one iris is detected correctly as shown in Fig. 4. In addition, eyebrow can contribute to failure in iris detection. If the subject frowns too hard, the eyebrow will be very close to iris. At the same time, if the iris is almost covered by the eyelid, a failure might also occur. However, this proposed algorithm has shown good accuracy in iris detection dealing with these types of situations. The iris detection rate can still be improved by using an eye template with more similarity compared with most of the images in the face database.

The processing time for mouth detection is 0.46 seconds per image compared to 2.04 seconds for iris detection as shown in Table 2. The simplicity of the algorithm for mouth detection has an advantage over algorithm for iris detection which is much more complicated. The image processing steps have done well in eliminating noises, beard, moustache and unwanted region. The detection rate for mouth

corners is 95.83% as shown in Table 1. Most of the failure cases are caused by 'mouth opened' as shown in Fig. 5 but there are also successful detections in this condition. This algorithm has shown a significant detection rate over the images with beard, moustache, facial expressions and certain orientations angles. Besides, this algorithm works well even with the conditions such as nose, less lips being shown and blurred color images.
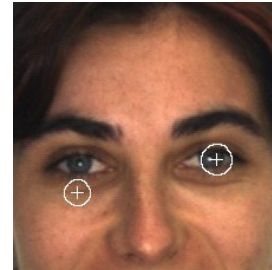

Fig. 4: Failure case – blue irises

Fig. 5: Failure case – mouth opened

6 Conclusion

According to previous researches, there are lack of mouth detection results dealing with facial expressions, beard, moustache, nose and long hair. This proposed algorithm has shown its robustness of facial features detection dealing with different kinds of subjects, genders, head tilts and facial features orientation angles. There are successful iris detections from incomplete detected face region and successful mouth detection from failure iris detection even the geometric information of irises is being used to obtain the mouth region.

In conclusion, the success rates of iris detection (93.06%) and mouth corners detection (95.83%) have to be improved in order to cope better with the situations discussed above. The steps for image processing need to be enhanced for better mouth corners detection rate. This algorithm will be tested with cases of eyes closed, external lighting form different directions and bigger face database. In future, this proposed algorithm will be used in the development of an automated face recognition system.

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