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Adaptive Face Region Detection and Real-Time Face Identification Algorithm Based on Face Feature Evaluation Function

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ABSTRACT

In this paper, we propose an adaptive face region detection and real-time face identification algorithm using face feature evaluation function. The proposed algorithm can detect exact face region adaptively by using skin color information for races as well as intensity and elliptical masking method. And also, it improves face recognition efficiency using geometrical face feature and geometric evaluation function between features. The proposed algorithm can be used for the development of biometric and security system areas. In the experiment, the superiority of the proposed method has been tested using real image, the proposed algorithm shows more improved recognition efficiency as well as face region detection efficiency than conventional method.

적응적 얼굴검출 및 얼굴특징자 평가함수를 사용한 실시간 얼굴인식 알고리즘

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요 약

본 논문에서는 적응적 얼굴영역 검출과 얼굴 특징자 평가함수를 사용한 실시간 얼굴인식 알고리즘을 제안하였다. 제안한 알고리즘은 명암도 정보와 타원마스킹 기법 뿐만 아니라 인종별 얼굴피부색을 사용하여 정확한 얼굴영역을 적응적으로 검출 가능하다. 또한 제안한 알고리즘은 얼굴 특징자 및 얼굴특징자간 기하학적 평가함수를 사용하여 얼굴 인식 효율을 개선하였다. 제안한 알고리즘은 생체인증 및 보안 시스템 분야에 사용 가능하다. 실험에서는 제안한 방법의 우수성을 입증하기 위해 실 영상을 사용하였으며 실험결과 기존의 방법보다 얼굴 영역 검출 뿐만 아니라 얼굴인식 성능을 개선하였다.

Key words: face detection(얼굴검출), face identification(얼굴인식), face feature evaluation function(얼굴특징평가함수)

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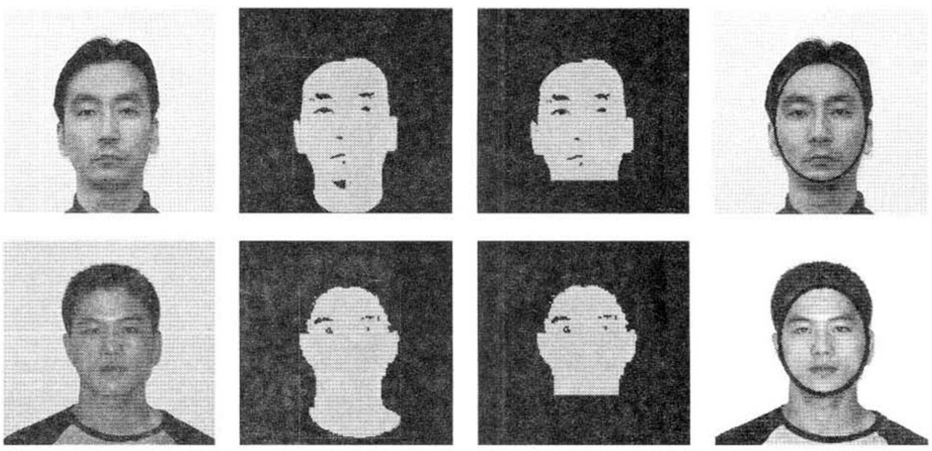
1. Introduction

As visual processing area using computers are getting advanced, studies related to human's bio-signal or visual system are in progress. Specially, studies about recognition of face, gesture and movement of humans face into animation are actively being performed. Moreover, as security related fields are considered important with development e-commerce, face recognition part has various uses and application range as well as being one of studies, which are most actively studied on. Information we can extract from face can be used at various fields, such as criminal search system, restriction of using personal computer, security system at public organizations, computer game, viewer search system of 3D TV and many others. Procedures of face recognition may be divided into three steps as whole face region detection, facial feature detection and face recognition. Namely, it detects face region and extracts constituent features like eyes, nose and mouth[1,3]. At last, it performs the last level, classification and recognition. However, current technology has restrictions with direction, color, brightness, races and other outer components. This paper detected primary face region candidate with using hue information of HSI coordinates to improve accuracy level in detecting face region. It also improved detection accuracy by allowing it to detect face region with intensity value, edge information, and elliptical mask. Moreover, it improved recognition efficiency by applying method using geometrical relation value, facial feature vectors, and four facial angles.

2. Adaptive Face Region Detection for Races Using Skin Color, Intensity, and Ellipse Masking

In face color chromaticity, people in same race have similar face color and they are massed around small range of color field[2]. In this paper, we used hue and intensity value from HSI color coordinate relatively similar to human's visual system to detect face region. For primary candidate face region, convert input color image into HSI color coordinates to get skin color tone information, and come up with labeling formula of massed objects by using hue value of skin color, and then the largest object among messed objects at certain range becomes candidate face region. From many standard image tests, primary candidate face region was very variable according to the hair, neck and clothes put on and the region showed the tendency of getting larger. Therefore, in this proposed paper, we detected face region by searching within the primary candidate face region range, and applying intensity value distribution, edge information and elliptical mask higher than the adaptively calculated threshold value of skin color information. Fig. 1 shows the results of face region detection.



(a) (b) (c) (d)

Fig. 1. Results of face region detection: (a) Original image: (b) Face region candidate (c) Face region (d) Ellipse masked image.

In Fig. 1, Fig. 1(b) is the image of candidate face region having similar distribution of skin color tone and intensity. Fig. 1(c) is the face region image using skin color, intensity and edge information and Fig. 1(d) is the image applied elliptical mask to marked face region in test image by using coordinates value from the elliptical face region[6]. Recognition computation and efficiency was improved by separating facial region from whole image to detect face region, and using calculated elliptical coordinate values of constituent objects, such as eyes, nose and mouth. In this paper, we measure skin color value based on the mongolian and also enabled face recognition by races with providing calculate HSI value for the caucasian and Negroid race.

Fig. 2 shows the process of detecting face region for the races. And also, Table 1 shows the skin color coordinates for the races, which acquired for the test sample images.

As shown in Table 1 from the HSI color coordinates by races, the caucasian race has the largest hue and intensity value. Among 226 male/female standard images used for the study, images detected exact face region and removed

Table 1. Color coordinate values for face color

Coordinate	H	S	I
Caucasian	27	163	210
Mongolian	23	170	179
Neogroid	20	198	106

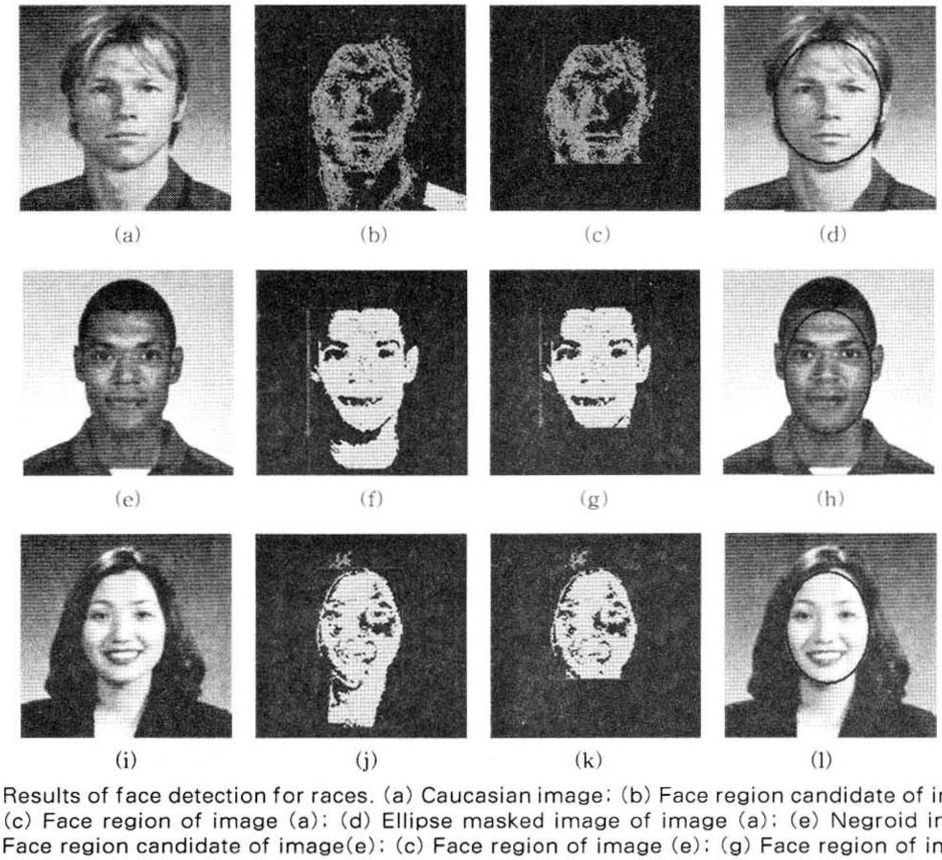


Fig. 2. Results of face detection for races. (a) Caucasian image; (b) Face region candidate of image(a); (c) Face region of image (a); (d) Ellipse masked image of image (a); (e) Negroid image; (f) Face region candidate of image(e); (c) Face region of image (e); (g) Face region of image (e); (h) Ellipse masked image of image (e); (i)Mongolian image; (j) Face region candidate of image(i); (k) Face region of image(i); (l) Ellipse masked image of image(i).

areas other than that were 216, which showed face region recognition rate of 95.5%.

3. Real-Time Face Recognition Based on Geometric Relation Evaluation Function Between Features

3.1 Facial Feature Detection Using Geometric Relation of Face

In this paper, intensity image of images converted into HSI coordinates to prepare detecting geometrical features of face is used. Geometrical feature detection is completed with applying horizontal Sobel operator, binary, dilation, labeling[3] based on the fact that facial characteristic aspects have many horizontal edges.

Fig. 3 shows the procedures of detecting features of eyes, nose and mouth through the preprocessing process. For the algorithm determining features of eyes, nose and mouth through preprocessing, we used relative geometrical position of both eyes and nose to determine two candidate eye position and one candidate nose position and one candidate mouth position having similar vertical axis coordinate. When following conditions are satisfied, set them in a pair as eyes within the area and the distance ratio is considered as a characteristic.

-Condition 1) The object stands on horizontal center line and also stands within symmetric y coordinate.

-Condition 2) If symmetric pairs are more than two, there should be a symmetric pair, which is located at lower position and has distance lower than the critical value.

Set an object qualified for following condition as candidate nose position and consider the distance rate as a characteristic.

-Condition 1) When it is located at lower than candidate eye area and at between them, and when difference in y coordinate is lower than critical value.

-Condition 2) If there are several qualified objects, select one located at higher position.

Set an object qualified for following condition as candidate mouth position and consider the distance rate as a characteristic.

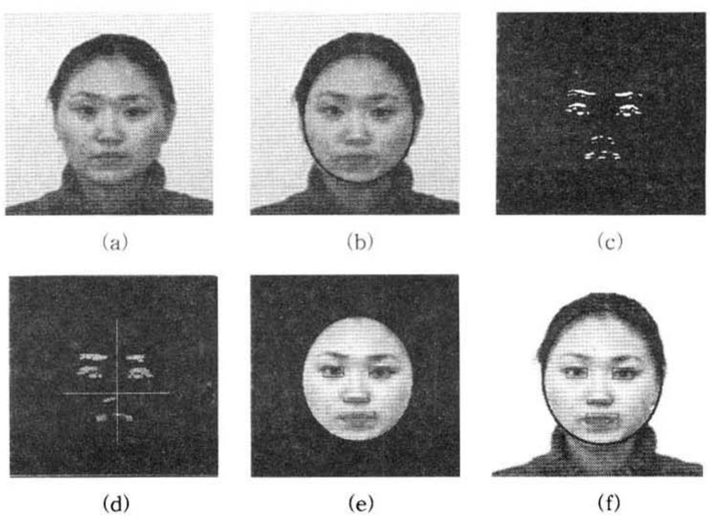


Fig. 3. Pre-processing and facial feature detection results: (a) Original image; (b) Face region image with ellipse masking; (c) Binary image; (d) Dilated image; (e) Labeled image; (f) Facial feature image.

-Condition 1) When it is located at lower than candidate nose position and at outside of both eye coordinate.

-Condition 2) If there are several qualified objects, select one with horizontal distance rate is high and located at higher position.

Calculate geometrical position value of related object from coordinates of face feature candidate region. Each face feature vector can easily be identified from face and each person shows differences with it. For comparison of these each face feature vector, the value, which compared relationship among geometrical positions of eyes, nose and mouth, is used.

In this paper, error in rate was lowered by using position of mouth, nose and eyes, and average value of lowest/highest value among them. Distance rate between characteristic points are calculated with Euclidean distance formula. Recognition with Euclidean distance formula (1) is normalized with standard deviation (σ). In formula (1)~(3), i is feature index, r_i is feature value of database, x_i is feature value of test image, m is number of DB image, and N indicates the image number of objects being recognized.

$$d^2 = \sum_i |X_i - r_i|^2 \qquad (1)$$

$$d^2 = \sum_i \frac{|X_i - r_i|^2}{\sigma_i^2} \qquad (2)$$

$$\sigma^2 = \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{m}\sum_{k=1}^{m}\left(r_{ijk} - \frac{1}{m}\sum_{k=1}^{m} r_{ijk}\right)^2\right) \qquad (3)$$

Among 226 male/female standard images used for the study, images detected exact characteristics of eyes, nose and mouth were 216, which showed face area recognition rate of 93%.

3.2 Face Identification Based on Face Features and Geometric Relation Evaluation Function Between Features

In the face recognition algorithm, we suggest face feature information, face angles and geometric relation evaluation function between functions. Fig. 4 shows the relative facial feature information for geometric relation evaluation function. Fig. 5 shows the proposed facial angle image and equation (4) is formulas for calculating facial angles from the facial features.

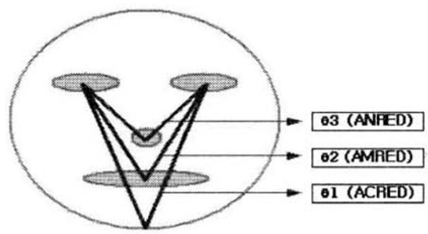


Fig. 5. Facial angle information

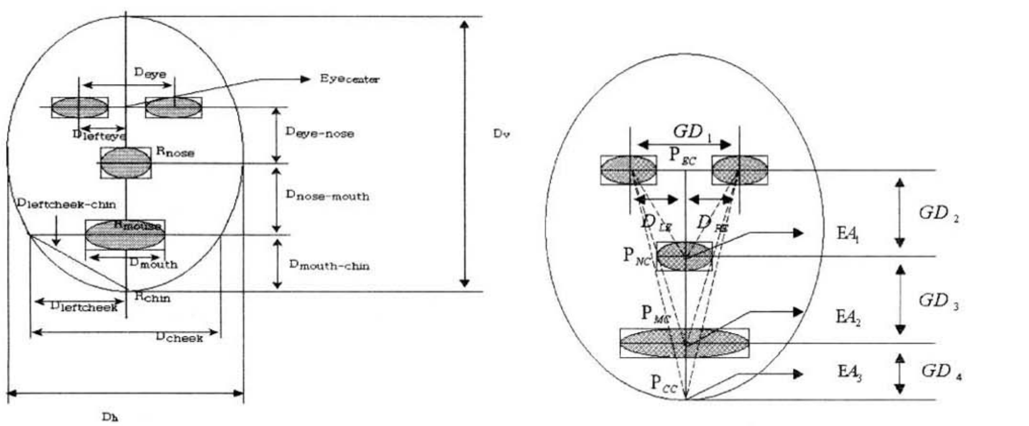


Fig. 4. Relative facial feature vector information

$$COS\theta_{EA1} = \frac{D_{LE-PNC^2} + D_{RE-PNC^2} - GD_1^2}{2D_{LE-PNC}D_{RE-PNC}}$$

$$COS\theta_{EA2} = \frac{D_{LE-PMC^2} + D_{RE-PMC^2} - GD_1^2}{2D_{LE-PMC}D_{RE-PMC}}$$

$$COS\theta_{EA3} = \frac{D_{LE-PCC^2} + D_{RE-PCC^2} - GD_1^2}{2D_{LE-PCC}D_{RE-PCC}} \quad (4)$$

where θ_1 is the angle at the center of both eyes from the center of chin, θ_2 is the angle of the center of mouth and both eyes and θ_3 is the angle of center of nose and eyes. For classifying and recognizing face image, facial angular difference of cosθ1, cosθ2 and cosθ3, determined from the calculating the rate of θ1, θ2 and θ3 is used.

Table 2 shows geometric facial angle of features from θ1, θ2 and θ3, which are considered as classification criterion in this paper. This distribution is divided into three geometrical types such as small, medium and large facial angle type. And also, Fig. 6 shows the resulting image for three facial angles on real images. We could notice that geometrical features and relation value of features may show some differences with people.

Geometric relation evaluation function between features is a function to define outer/ inner face type and relative distance between features.

Table 2. Classification results for facial angles

Type	Small angle type	Medium angle type	Large angle type
θ1	30°~34°	34°~40°	40°~45°
θ2	44°~47°	47°~50°	50°~53°
θ3	59°~64°	64°~69°	69°~74°

Equation (5) shows the geometric relation evaluation function. In this paper, for the identification of person's face, we use geometrical position value of eyes, nose, mouth and chin in face region, facial angle value of chin reference to eye distance, mouth reference to eye distance, and nose reference to eye distance and evaluation function of equation (5).

$$F_{type} = \frac{1.2D_h}{D_v}$$

$$C_{type} = \frac{1.2D_{eye}}{D_{eye-nose} + D_{nose-mouth}}$$

$$D_{eye} = D_{lefteye} + D_{righteye}$$

$$D_{eye-nose} = Abs(D_{eyecenter} - R_{nose})$$

$$D_{nose-mouth} = Abs(R_{nose} - R_{mouth})$$

$$D_{mouth-chin} = Abs(R_{mouth} - R_{chin}) \quad (5)$$

4. Experimental Results

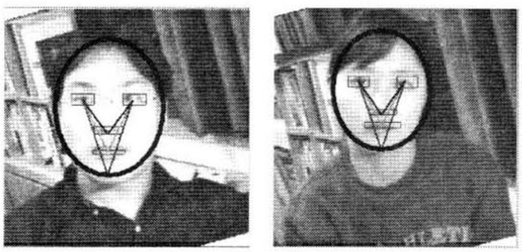
In this paper, not complicated background and fixed lighting were restricted for experiment environment. For accurate and reliable sampling of face region, various steps were applied successfully. In this paper, we use 226 male/female standard images for the detection and recognition of face. Fig. 7 shows the results of face features and facial angles. Fig. 7(a) is the image, extracted facial features from face image, and Fig. 7(b) is the result image describing facial angle of features. Fig. 8 shows the results of facial feature vector extraction in real-complex background condition.

(a) A type (b) B type (c) C type

Fig. 6. Face type for three facial angles

(a) (b)

Fig. 7. Facial feature vector extraction: (a) Resulting image for facial features; (b) Resulting image for facial angles.



(a) (b)

Fig. 8. Facial feature vector extraction in real-complex background: (a) Resulting image for facial features; (b) Resulting image for facial angles.

Table 3 shows the comparison results of conventional feature based method with proposed algorithm for sample images. As you can see in this table, there was many medium facial angle type. Among 216 face region images used for the detection of facial features, images detected exact features of face were 208, which showed face feature extraction rate of 96.3%. And, Fig. 9 shows the GUI of real-time facial identification system.

6. Conclusions

In this paper, adaptive face detection and identification algorithm, by using face color for races, elliptical mask, face features, facial angles, and geometric relation evaluation function is proposed. In the proposed algorithm, we have improved the face recognition as well as the face region detection efficiency. For securing enough data, solving problems related to face recognition and identification process and embodying system for real time application, effective and real environment oriented methods should be studied.

Table 3. Detection and recognition results for proposed algorithm.

Process	Face Detection	Feature Detection	Face Recognition	Total Image
Images (conventional/proposed)	210/216	205/208	192/197	226
Conventional method (without facial angles)	93	91	85	100%
Proposed method (with facial angle)	95.5	92	87.2	100%

Fig. 9. GUI of facial identification algorithm

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