METHODS OF EYEBROW REGION EXTRACRION AND MOUTH DETECTION FOR FACIAL CARICATURING SYSTEM PICASSO-2 EXHIBITED AT EXPO2005

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ABSTRACT

We have researched and developed the caricature generation system PICASSO. PICASSO outputs the deformed facial caricature by comparing input face with prepared mean face. We specialized it as PICASSO-2 for exhibiting a robot at Aichi EXPO2005. This robot enforced by PICASSO-2 drew a facial caricature on the shrimp rice cracker with the laser pen. We have been recently exhibiting another revised robot characterized by a brush drawing. This system takes a couple of facial images with CCD camera, extracts the facial features from the images, and generates the facial caricature in real time.
We experimentally evaluated the performance of the caricatures using a lot of data taken in Aichi EXPO2005. As a result it was obvious that this system were not sufficient in accuracy of eyebrow region extraction and mouth detection.
In this paper, we propose the improved methods for eyebrow region extraction and mouth detection.

Keywords: caricaturing robot, performance evaluation, eyebrow region extraction, mouth outline extraction

1. INTRODUCRION

We have researched and developed the caricature generation system PICASSO [1]. We succeeded in the automation of the PICASSO system called PICASSO-2. We exhibited the robot that used PICASSO-2-system in the Aichi Expo EXPO2005 (Prototype Robot Exhibition). [2] The robot is called COOPER.

The image processing system for COOPER takes a couple of facial images with CCD camera, extracts the facial features from the image, and generates the caricature. The facial image processing system is designed for recognizing irises, nostrils from the facial images first, and defines the respective regions involving eyes, nose, mouth, and ears guided by the positional relation among irises and nostrils. The hair region and skin region surrounding these regions of the face are also defined, and the shape features of the each facial part are detected. In the final result, this system generates the caricature comprising by 251 feature points that are defined originally as the PICASSO-2 format. This system evaluates simultaneously the quality of the intermediate results including caricature by using "fail-safe system".

2. DETAILS OF IMAGE PROCESSING SYSTEM

2.1 Detection of skin region

As the preprocessing for extraction of facial features, this system detects skin color region from RGB image. In the preprocessing, blue region of the background is eliminated from the input image. And therefore the skin color region is detected from the input image as shown in Fig. 1 based on the hue discrimination as shown in Fig. 2. This skin color region is defined and used for the successive image processing.

2.2 Extraction of irises and nostrils

In this system, irises are first extracted by using Hough transform [3] for leading other hierarchical processing modules. Secondly nostrils are extracted in the same way of irises at the nose region. The results of irises and nostrils are shown in Fig. 3.

2.3 General information

The regions of eyes, nose, mouth and ears are defined by using the information on irises and nostrils. As defined in each facial parts region, outlines of eyes, nose, mouth and ears are detected from the input gray image by using smoothing, contrast enhancement, binarization and thinning procedures, as shown in Fig. 3.

2.4 Contour detection

We basically designed that the caricature of COOPER is represented with a set of line drawings. This means that the face of line drawings is less informative than the original image in physical meaning, but that the face of line drawings is more effective than the face image in impression. In this sense, the shape feature of the face contour, hair and jaw is more dominant than the gray image. Moreover the fact that the face of line drawings is easier to realize the correspondence among faces than the face images is one of the technical advantages.

The outline of hair is detected from the binary image by the method of smoothing, contrast improvement and binarization with threshold, as shown in Fig. 4.
The outline of jaw is detected from R image of RGB color image by using Sobel operator and thresholding, as shown in Fig. 5.

2.5 Fail-safe principle and its implementation

At the same time of the extraction of facial parts, this system evaluates how feasible the result is, and modifies the result, if necessary, according to the statistical standard for the positional relationship among facial parts. This fail-safe system evaluates the result by the estimation function preliminarily prepared [4] which was defined by the difference between the result of the input face and mean face. If this system fails eventually in the result, the results are automatically replaced by the corresponding facial parts of the mean face and fitted it as the facial parts.

2.6 Caricature generation

COOPER system inherits the basic mechanism of deformation from the original system PICASSO. Facial caricaturing system PICASSO which extracts some facial individuality features from the input face and deforms these features to generate a caricature. The facial caricature Q is generated by comparing the input face P in Eq. (1) with the mean face S, which is defined by averaging input faces as shown in Fig. 6. This system introduces the exaggeration rate b for adjusting the deformation of the caricature to each visitor.

$$Q = P + b(P - S) \quad (1)$$

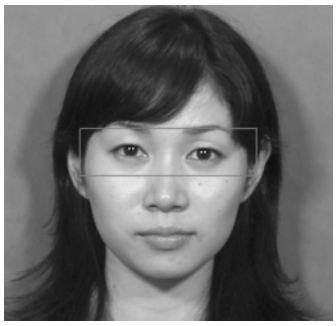


Fig 1. Input face

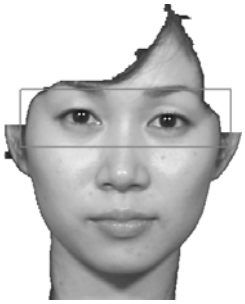


Fig 2. Skin color region

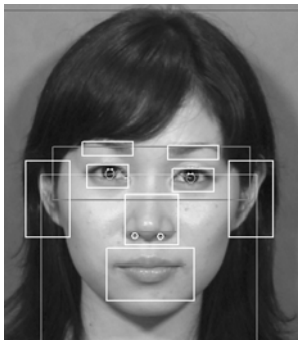


Fig 3. Example of facial features extraction

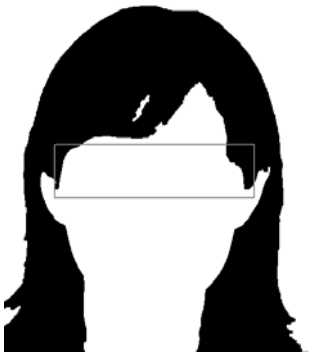
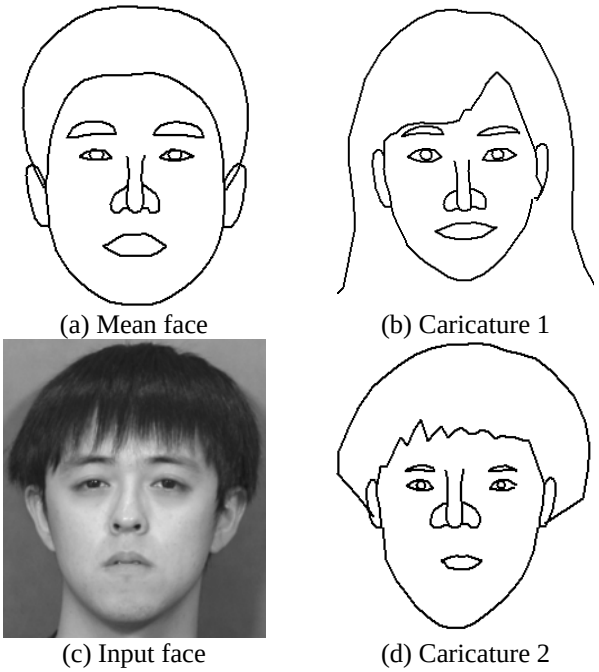


Fig 4. Hair region

Fig 5. Pre-processing of jaw extraction



(a) Mean face (b) Caricature 1

(c) Input face (d) Caricature 2

Fig 6. Example caricature generation

3. EVALUATION EXPERIMENTAL RESULT OF FACIAL RECOGNITION

We investigated the recognition performance of each facial part from the view point of recognition accuracy. The extraction rates of each facial part area were evaluated by watching and scoring with five grades, and the result shown in Table 1 was obtained.

We evaluated the nostril approximated circle and the background removal of the area extraction, by extracting the outline and additional facial parts. We looked for the improvement point as a result. We found that the recognition performances of the eyebrow area, the outline, the mouth area, and the ear are more insufficient than that of this evaluation experiment.

Table 1 Results of five-grade evaluation experiment

	Region Extraction		Outline Extraction
eyebrow	3.27	Eyebrow	2.37
Eye	4.79	Eye	3.93
		Irises	3.66
Nose	4.79	Nose	3.86
nostril	3.97		
mouth	4.92	Mouth	3.04
Jaw	4.65	Jaw	3.34
Hair	4.52	Hair	4.03
		Ear	2.35
		background removal	4.66

4. EYEBROW REIGION EXTRACTION

When the accuracy of the area extraction is improved, the eyebrow has the possibility to be improved also by the face outline extraction. Then, the eyebrow area extraction can be also improved by coupling the related results of the facial parts. The position of the eyebrow can be easily assumed from the location information of circles of the pupil and the nostril in the eyebrow area extraction so far.

In the proposed method, the contrast between the extracted area and the adjacent area is precisely investigated, and the extracted area is moved step by step so that the difference of the gray values between the adjacent upper and lower regions falls below the threshold.

At the moment of the exhibition of the Aichi Expo2005, we evaluated the quality of the eyebrow area extraction by using 100 data among total 352. If the detection of the shifted area was improved for instance by 0-20%, the score in five grades was evaluated to be improved as 1 by the intensive human visual inspection.

In the proposed algorithm, let the average gray values B_{top}, and B_{bottom} be obtained. Next, when the difference between B_{top}, and B_{bottom} is greater than or equal to the thresholds th_{low}, it moves vertically in the direction where the average gray value becomes low. This processing is repeated until the difference of the average gray values becomes below the threshold as shown in Eq. (2), and is ended when the minimum y coordinate value $eye_{\min}$ of the pupil approximation circumference becomes equal to y coordinate value ey at just below the eyebrow area, and when the pupil and the eyebrow areas exist together. When the hair becomes across the eyebrow area, the processing is ended without being moved the eyebrow area from an initial position of the threshold th higher or less than the average gray value of the surface. Fig 7 shows the position of the average gray value in which the processing area is calculated.

$$B_{top} = \frac{1}{ex - sx}\sum_{i=sx}^{ex} f(i, sy)$$

$$B_{bottom} = \frac{1}{ex - sx}\sum_{i=sx}^{ex} f(i, ey)$$

$$\begin{aligned} B_{top} \le B_{bottom} &\Rightarrow sy-1, ey-1 \\ B_{top} \ge B_{bottom} &\Rightarrow sy+1, ey+1 \\ |B_{top} - B_{bottom}| \le th_{low} &\Rightarrow end \\ B_{top} \le th_{high} &\Rightarrow end \\ eye_{\min} = ey &\Rightarrow end \end{aligned} \tag{2}$$

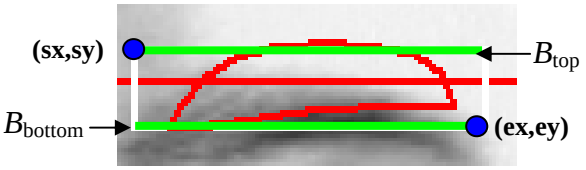
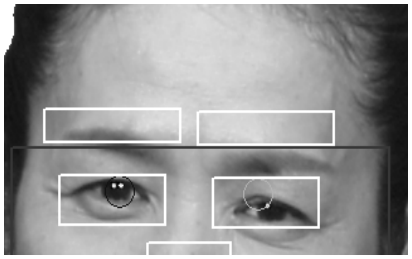
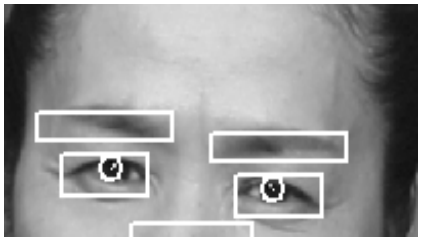


Fig 7. Extraction of eyebrow region

Fig. 8 shows a pair of the examples of the eyebrow area extractions for demonstrating the efficiency of the proposed method. The score of the original method was evaluated as 3.27 so far. The average score of the proposed method was improved to be 4.41, therefore in the proposed method contributed to realize the improvement of 1.14 grades in average. As a result, around 30% increase of success rate of eyebrow extraction was provided.



(a) Previous method



(b) New method

Fig 8. Eyebrow region extraction

5. MOUTH OUTLINE DETECTION

Mouth region is extracted comparatively accurately. Though, mouth outline detection is low in accuracy. Then we propose the improvement method of the mouth detection. We experimented how precisely the system could extract the mouth outline using RGB color system. As a result, in case of using red of RGB color system, it is suitable for shading extraction. And in case of green of color system, it is suitable for shading and lip extraction. Shadow is made at the lower lip easily though it is not made at the upper lip. We proposed a method based on the color information: the recognition of mouth outline by using the individual application of red and green information to the upper and lower outline of the mouth. In our proposed method, outline of upper lip was extracted successfully by the green of RGB color system, and outline of lower lip was extracted successfully by the red of it.

Fig. 9 shows an example of the extracted mouth region. Fig. 10 show the extracted outline by red and green of RGB color system.

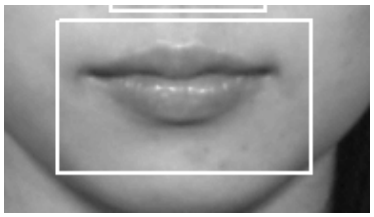


Fig 9. Extracted mouth region

(a) Outline extraction by red of RGB color system

(a) Outline extraction by green of RGB color system

Fig 10. Mouth outline extraction

6. SUMMERY

In this paper, we investigated intensively the performance of the facial caricaturing robot COOPER exhibited at EXPO2005, and based on the investigations. As a result it was obvious that this system were weak in accuracy of eyebrow region extraction and mouth detection. We showed the possibility of making the system robust by detecting the eyebrow outline. Moreover, we proposed method that the method could extract upper lip using green of RGB color system, and it could extract lower lip using red of RGB color system. As the future tasks, this system must be more robust to the unexpected changes of the illumination and to the spontaneous movement of the head of a person sitting in front of the camera. Moreover, we should take countermeasures for noise in the image.

7. REFERENCES

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