Fig.1 Exterior view of COOPER

Fig. 2 Example of the facial caricature on the shrimp rice cracker

Fig. 3 Blue backrest chair and touch-sensitive panel

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. 4 based on the hue discrimination as shown in Fig. 5. 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 [6] 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. 6.

2.3. Facial parts detection

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, thresholding and thinning procedures, as shown in Fig. 6.

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 thresholding, as shown in Fig. 7.

The outline of jaw is detected from R image of RGB color image by using Sobel operator and thresholding, as shown in Fig. 8.

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 [7] which was defined by the difference between the result of the input face and mean face. If this system rejects the result, it is 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 with the mean face S, which is defined by averaging input faces as shown in Fig. 9 and Eq. (1). This system introduces the exaggeration rate b for adjusting the deformation of the caricature to each visitor

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

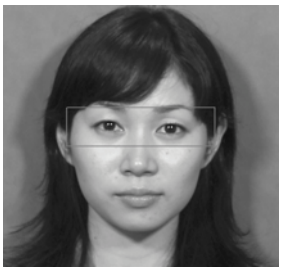


Fig. 4 Input face

Fig. 5 Skin color region

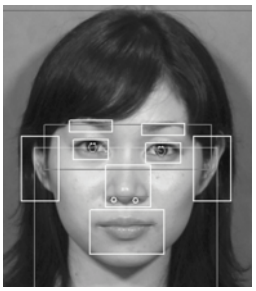
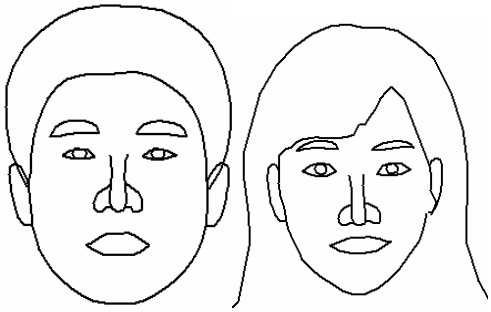


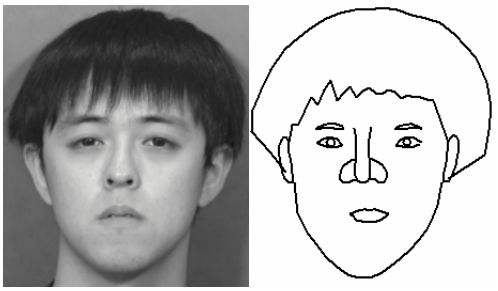
Fig. 6 Example of facial features extraction

Fig. 7 Hair region

Fig. 8 Pre-processing of jaw extraction



(a) Mean face (b) Caricature 1



(c) Input face (d) Caricature 2

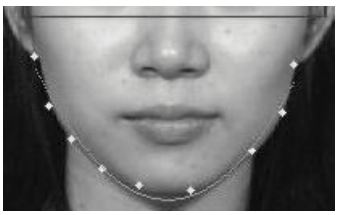
Fig. 9 Example of caricature generation

3. EXPERIMENTS

During 11 days in the Aichi Expo2005, COOPER manufactured 352 facial caricatures almost successfully and presented them to the visitors. Afterwards, the total evaluation of these caricatures by the intensive observations was executed, and the result shown in Table 1 was obtained.

As the result of the above detailed evaluations, the lack of quality in jaw parts detection caused a lot of failure examples in facial caricature generation. Some intensive investigation lets us know that a person with unclear boundary between mandible and neck, with a thick beard and/or with the dark shadow on the cheek are likely to be failed in caricature generation.

Inspired by these considerations, it is expected to enforce this system from both bottom-up and especially top-down procedures. As the top-down procedure, we introduced the curve fitting methods by means of several analytical curves such as polynomial and B-Spline functions. Fig. 10 shows a couple of examples of the preliminary experiments. As known from these results, it would be promising to reduce the side effect of the noise, and further more to make the facial caricaturing robot COOPER be automated.

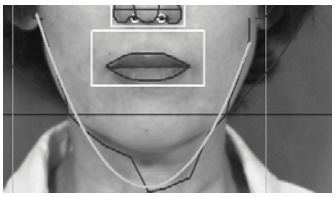


(a) Least mean square approximation

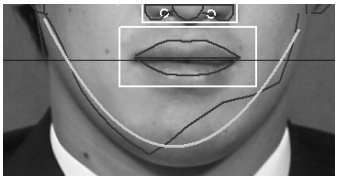
(b) B-Spline

Fig. 10 fitted contour line

In Fig. 11 and Fig. 12, we show some experimental examples of the curve fitting by analytic functions to the jaw contour which was detected as the typical one of the failures. This system is likely to fail to extract a natural jaw contour as shown in Fig. 11 (a) and/or to succeed as shown in Fig. 11 (b) when least mean square approximation is used. On the other hand, this system failed both Fig. 12 (a) and Fig. 12 (b), when 'B-Spline' fitting is used.

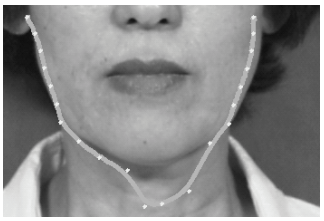


(a) case1

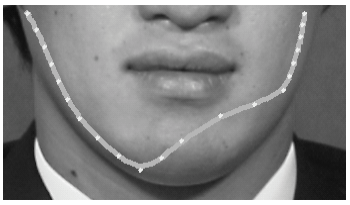


(b) case 2

Fig. 11 Least mean square approximation



(a) case1



(b) case2

Fig. 12 B-Spline

4. SUMMARY AND FUTURE TASKS

In this paper, we investigated intensively the performance of the facial caricaturing robot COOPER exhibited at EXPO2005, and based on the investigations, in order to enforce the bottom-up image processing we introduced a top down curve fitting architecture to extract the natural contour of the jaw and a few preliminary experiments were executed. Then we could experimentally show the possibility to introduce a curve fitting method as one of the top-down procedures. As the future tasks, it is expected to remove the random noise prior to the proposed top down procedure, and it is also expected to make the gradient operators be more adaptive to the detailed shape of the facial parts. Moreover, 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.

5. REFERENCES

[1] Robot Project: Prototype Robot Exhibition: http://www.expo2005.or.jp/jp/C0/C3/C3.8/C3.8.2/C3.8.2.6

[2] Caricaturing robot, EXPO'85, Matsushita pavilion:http://www.mid.co.jp/mid/shirahama/nigaoe.html

[3] E. Takigawa, H. Kishiba and M. Kawade: @faceAutomatic Gender and Age Estimation with Face, Proc. of the Conf. on Japanese Academy of Facial Studies 2002, p171 (2002)

[4] K. Teranishi, N. Kotani and M. Shinya: Chara-Face:Aportrait Caricaturing System, Proc. of General Conf. on IEICE, A-14-5 (2000)

[5] H. Koshimizu: Computer Facial Caricaturing, Trans. The Institute of Image Information and Television Engineers, Vol.51, No.8, pp. 1140-1146 (1997.8).

[6] T.Funahashi, T.Fujiwara, M.Tominaga, and H.Koshimizu: Hierarchical Face and Facial Parts Tracking and Some Applications, Prod. of 7th International Conference on Quality Control by Artificial Vision, pp. 305-310, Japan (2005)

[7] T. Fujiwara, R. Ushiki, M. Taga and H. Koshimizu: A Method of Facial Attribute Classification based on Statistic Analysis of the Relationship among Facial Parts, Journal of Japanese Accademy of Facial Studies, Vol.2 No.1, pp. 25-38 (2002)

Table 1 Experimental result

A: The number of generated caricatures,
B: The number of successful generation of caricature,
C: The number of unsuccessful extraction of irises and nostrils and successful extraction from the 2nd frame,
D: The number of the fitting by mean face,
E: The number of cases that were recovered by FFS,
F: The number of failures below the constant standard in the visual inspection,
G: The number of cases that failed fatally,
H: The ratio of the successful cases to the total number of the caricatures,
I: The ratio of the successful cases to the total number of the caricatures by using FSS,

	6/9	6/10	6/11	6/12	6/13	6/14	6/15	6/ 16	6/17	6/18	6/19	total
A	46	33	30	29	29	31	32	33	35	34	20	352
B	34	25	22	21	17	19	26	30	17	28	14	253
C	4	0	2	0	2	1	1	1	1	0	1	13
D	4	8	4	8	8	8	4	0	14	3	3	64
E	8	8	6	8	10	9	5	1	15	3	4	77
F	3	0	1	0	2	3	1	2	2	3	2	19
G	1	0	1	0	0	0	0	0	1	0	0	3
H	73.91	75.76	73.33	72.41	58.62	61.29	81.25	90.91	48.57	82.35	70.00	71.88
I	91.30	100.00	93.33	100.00	93.10	90.32	96.88	93.94	91.43	91.18	90.00	93.75