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3—21 On the Detection of Feature Points of 3D Facial Image and Its Application to 3D Facial Caricature

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Abstract

This paper proposes an automated method for extracting 39 feature points from 3D facial image, and shows that 3D facial caricaturing can be realized by such these smaller number of feature points and that these 39 feature points could be extracted automatically.

As a result, it was clarified by comparing 3D caricature of 3D PICASSO system with that of a famous caricaturist Mr. Yoshida that 3D features of the facial image could be utilized to generate more impressive facial caricature then the 2D one.

1. Introduction

Facial caricature illustrators catch characteristics and personality features of the face clearly, and they draw the facial caricature by exaggerating them skillfully. As for their observation process, they extract the shape, size, color and emotions of the face, and they draw the caricature with a process of these personal characteristics detection. It is easily known that these personality characteristics can be drawn by transforming them in the various ways of expressions as a facial caricature that is finally very sensitive.

In our laboratory, we are developing the facial caricature system, which extract the characteristics of the face taken from the face image, and deforms these characteristics. This 2D facial caricature system PICASSO has been developed. Thus the scope of the features of the face could be extended to the 3D shape of the face, and the 3D shape of the face can be repressed by range data of the face.

In this paper, the 3D caricaturing system which recognizes each region of the face automatically is introduced. Up to now, this 3D facial caricaturing system was developed by using 189 feature points, which are provided mainly by the hand-operated works. This paper proposed an automatic method to detect feature points and 39 effective feature points could be extracted automatically. Consequently, it was clarified that 3D facial caricature could be realized, and that 3D facial caricature could be more impressive to the viewers than 2D one. In each chapter, in chap.2, the principle of PICASSO system was summarized. In chap.3, the details of the method to extract feature points was presented, and in chap.4 3D facial caricaturing system was introduced and its validity was clarified experimentally.

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2. "Mean face" assumption and PICASSO system

The PICASSO system exaggerates individuality features for generating the caricature. As for the basic principle of PICASSO, the facial caricature Q_{2D} could be generated by comparing the input face P_{2D} with the mean face S_{2D} which is defined by the averaging of input faces. We call this idea as "Mean face hypothesis" for facial caricaturing. The individuality features can be expressed by the vector (P_{2D} - S_{2D}), and the parameter b indicates the deformation rate. The general idea of PICASSO is shown in eq.(1) and an example is shown Fig.1.

$$Q_{2D} = P_{2D} + b\,(P_{2D} - S_{2D}) \qquad (1)$$

Next, the rough flow of the 3D caricaturing and its principle are introduced. First, the original 3D face data is taken by using range finder. After the preprocessing of facial parts, the face data is normalized by Affine transform for adjusting all of input faces. The difference between the input data P_{3D} and "mean 3D face" S_{3D} can be utilized to generate 3D facial caricature Q_{3D} as given in the eq(2). This general idea of 3D caricaturing is shown in Fig.2. Thus, the basic principle of 3D caricaturing is the same as the 2D one.

$$Q_{3D} = P_{3D} + b\,(P_{3D} - S_{3D}) \qquad (2)$$

Two types of input data were used, first one is the 3D range face data and the other is the gray image completely registrated with each other. By using this augmentation of the dimensionality, the shapes of the 3D form of them are precisely acquired and 3D impressions of the face could be effectively exaggerated.

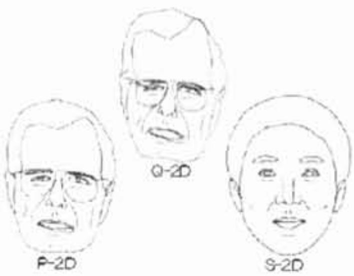

Fig.1. The principle of 2D-PICASSO system.

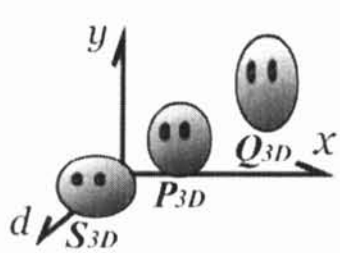

Fig.2. General idea of the 3D facial caricaturing.

3. Automatic detection of facial parts region

First, feature points are extracted from the range data. The origin is taken at the upper left, and x-axis is taken in the horizontal, and y-axis is taken in the vertical direction. The (x, y) coordinate that gives the maximum value of the 3D range image becomes a nose apex (x_{max}, y_{max}). Next, some of local maximum peeks are searched upward and downward by the nose apex, and 3 points in the upper part and 7 points in the lower part are extracted. An example is shown in Fig.3.

3.1. Detection method of nose region

The coordinates of top and bottom boundaries are defined by $y_u^{(1)}$ and $y_b^{(1)}$, respectively. And, left and right boundaries are obtained by scanning the range data in the x-axis direction from the point of nose vertex. The nose region is defined by eq.(3), and an example is shown in Fig. 4.

$$\{(x,y) \mid x_{(L,n)} \leqq x \leqq x_{(R,n)}, y_{(U,n)} \leqq y \leqq y_{(B,m)}\} \quad (3)$$

3.2. Detection method of the mouth region

The coordinates of top and bottom boundaries are defined by $y_b^{(1)}$ and $y_b^{(5)}$, respectively. And, left and right boundaries are obtained by scanning the range data in the x-axis direction from the point of $y_b^{(3)}$. The mouth region is defined by eq.(4), and an example is shown in Fig.5.

$$\{(x,y) \mid x_{(L,m)} \leqq x \leqq x_{(R,m)}, y_{(U,m)} \leqq y \leqq y_{(B,m)}\} \quad (4)$$

3.3. Detection method of the eye region

The top and bottom boundaries are two horizontal lines pair which pass $y_u^{(2)}$ and $y_u^{(0.5)}$ which are the middle of nose apex and $y_u^{(1)}$. Left and right boundaries are the x-coordinates on the both saides of the face range image. The eye region is defined by eq.(5), and an example is shown in Fig.6.

$$\{(x,y) \mid x_{(L,e)} \leqq x \leqq x_{(R,e)}, y_{0.5}^{(U)} \leqq y \leqq y_2^{(U)}\} \quad (5)$$

3.4. Detection method of the face outline

The apex of the nose is put to the origin, and it is scanned to find the borderline of the face along x-axis, y-axis, $y=x$, $y=-x$, $y=2x$, $y=-2x$, $y=1/2$ and $y=-1/2$. At this time, because the position of the upward point of the eye region and the top of $x=y$ and $x=-y$ is near, it isn't scanned. And, because there was a neck, 3 points of the bottoms (y-axis, y=2x and y=-2x) were extracted by thresholding. An example is shown in Fig.7.

3.5. Making triangular patch and 3D mean face

The 3D surface of the face was constructed by triangular patches, which are defined by the feature points. The triangular patches are composed of 8 points along the corner of the screen. Each 68 patches are corresponding among the different faces, and each 3D surface data is normalized by Affine transform. Fig.8 shows an example of the generated triangular patches. Within each triangular patch, the mean of the height value is calculated for every pixel by the following eq.(6), and the average distance face image "3D mean face" S_{3D} was made. Fig.9 shows one of the examples (average of 8 and 16 people).

$$x_i^{(S)} = \frac{1}{N}\sum_{j=1}^{N} x_i^{(j)}, y_i^{(S)} = \frac{1}{N}\sum_{j=1}^{N} y_i^{(j)}, z_i^{(S)} = \frac{1}{N}\sum_{j=1}^{N} z_i^{(j)} \quad (6)$$

Let us compare the mean face given above with the mean face introduced manually with 189 feature points, in order to show the feasibility of the proposed method of this paper. Fig.10 shows an example of the previous method with 189 feature points. Even by the proposed method with 39 feature points, the facial surface could be successfully expressed except at the boundaries of the hair, where the range data can not be originally acquired. In addition to this, as all 39 feature points can be extracted automatically, it is obvious that the proposed method would be superior to the previous one.

Fig.3 Example for local peeks.

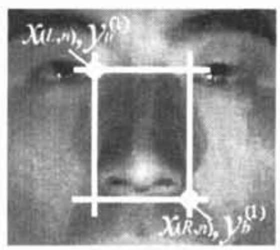

Fig.4. Nose region.

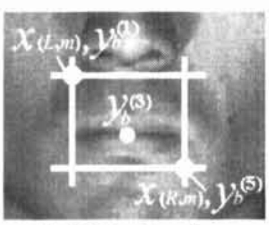

Fig.5. Mouth region.

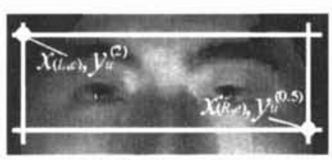

Fig.6. Eye region.

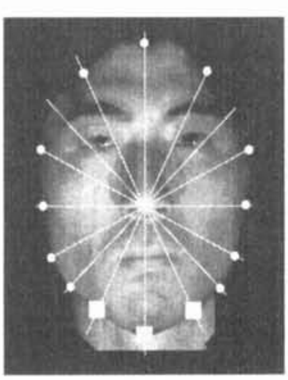

Fig.7. Points of the outline.

Fig.8 The triangular patches.

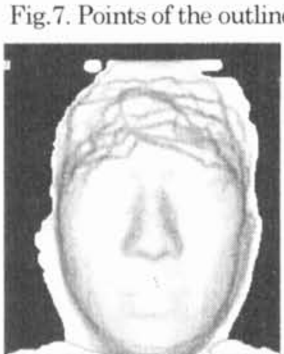

Fig.9. 3D mean face. (39 points)

Fig.10. 3D mean face. (189points)

4. 3D facial caricaturing

4.1. Method of 3D facial caricaturing

Based on 3 vertexes of the input face P and 3 vertexes of the mean face S, the caricature Q is calculated by eq.'s(7) and (8).

$$x_{(j)}^{(Q)} = x_{(j)}^{(P)} + b(x_{(j)}^{(P)} - x_{(j)}^{(S)}) \tag{7}$$

$$y_{(j)}^{(Q)} = x_{(j)}^{(P)} + b(x_{(j)}^{(P)} - y_{(j)}^{(S)}) \tag{8}$$

The height value of caricature Q is calculated by using the height value of input face P and mean face S by corresponding to every pixel which is calculated by the linear interpolation given in eq.(9).

$$z_{(x,y)}^{(Q)} = z_{(x,y)}^{(P)} + b(z_{(x,y)}^{(P)} - z_{(x,y)}^{(S)}) \tag{9}$$

4.2. Result of facial caricaturing experiment

In this section, we show experiments of the caricaturing. 3D caricaturing results are shown in Fig.11. In this case, the caricatures were made with the value of deformation rate 100%. Comparing these two caricatures, the respective individuality characteristics are successfully exaggerated. For example, as the swell of the cheeks are exaggerated adequately and this feature is common to these faces. We can get the good result, even if the feature points are decreased to 39, as shown by these experimental results. And this method has an advantage that the feature points are detected automatically.

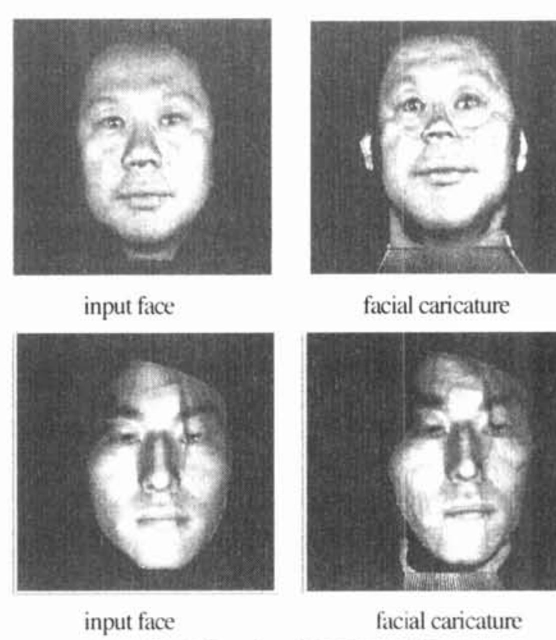

Fig.11 Results of 3D-PICASSO.

5. Consideration

We could get the good mean face, which could suppress the individual characteristics sufficiently, even if the number of the feature points is decreased to 39. Furthermore, it is possible to make the 3D caricature by using only 39 feature points. Figure 12 shows the comparison with the other caricature generated by 189 feature points.

Figure 13 shows the comparison of the caricature generated by our system with the caricature given by a professional illustrator, Mr. K, Yoshida. And, it was demonstrated the feasibility of this algorithm was proved. We can see that both caricatures are well deformed in the similar characteristics of this model.

(a) By automatic extraction (b)By manual input 189 points

Fig.12. Comparison of the each technique.

(a) Illustration of Mr. Katsuhiko Yoshida (b) By 3D PICASSO

Fig.13 Comparison with the illustrator.

6. Conclusion

This paper presented the methods for the preparation of the mean face by the automatic feature points extraction of the characteristic point of the 3D face image, for the generation of the triangular patch and for the deformation of the caricature. Until now, it was clarified that the input time for the facial caricaturing could be shortened by the automatic extraction of characteristic points. Yet, this method is not enough in precision and in robustness to realize the extraction of the characteristic point. For example, if the recognition precision could not be realized well at the apex of the nose, other characteristic points could not fatally be detected at the correct position. Therefore, it is necessary to enforce the extraction precision especially of this characteristic point.

7. Acknowledgement

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