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On a Simple Method for Corresponding 3-D Facial Images and Its Application to Generate Facial Caricature

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Abstract

We propose a method to generate a facial caricature depending on a simple method for corresponding 3-D facial images. In this method, we extract several facial parts regions each of which include facial parts of the face by using both gray and range images. The diagonal corners of the respective extracted regions are used to provide the informations on the correspondence between the faces. Therefore, by using this method, it is expectable to reduce the number of the feature points for the correspondence from more than several hundreds to ten or so.

In order to examine the feasibility of this method, we employ a usual corresponding method of the triangular patch as the reference. We generated the ***3-D mean face*** *and* ***3-D facial caricature*** *to demonstrate experimentally the feasibility of the proposed method. It was thought that the number of the correspondence points can be reduced to only 10% of the usual method.*

1. Introduction

Artist and illustrator are superior in the skill of facial features extraction. In the process of their face observation, it is thought that they exactly catch features of position and shape of the face. They exaggerate these features skillfully. Then, they draw them finally as a impressive facial caricature.

Facial caricaturing is a process of the feature extraction and feature exaggeration of faces. Not only gray-level images, we are expected to open the door to utilize more wide informations on the face such as color, motion and range informations. Now in this paper, we paid attention to the range information for the extension of the spatial dimensionality of the face. For this extension, we made use of the range image of faces and 3-D facial caricature (or facial 3-D relief) is introduced by using the range image.

Now, in case that we generate such 3-D facial caricature, it is necessary generally to designate many correspondence points in the face image. In this paper, we consider that the number of the correspondence points can be reduced by a simple method using 7 facial parts regions. At first, we state about the simple method to extract the sub-region of a facial part automatically by using together face range image with gray-level image. Then, we experiment on the robustness of this method by means of extracting 3-D mean face and generating 3-D facial caricature. Then, we confirm that 3-D facial caricature can be exaggerated by this simple method.

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2. Outline of 3-D Facial Caricaturing

We propose the following fundamental principle to generate 3-D facial caricature.

(1) This proposed method can make the 3-D facial caricature by a few facial parts rectangle regions.
(2) This proposed method gives automatically the correspondence points by using range image and gray-level image.
(3) If this proposed method becomes a practical tool, we can make it clear that the proposed method can extract sufficient from the 3-D image data.

Now, as shown in **Figure 1**, let the process of 3-D facial caricature be composed. And in this method the whole face region is divided into seven sub-regions (eye, nose, mouth, head, chin, right cheek, and left cheek). Mean faces for each sub-regions are generated respectively from each sub-region. Facial individuality features are extracted respectively in each sub-region by comparing with the mean sub-regions. These individuality features are exaggerated, and finally, all seven deformed faces of the each sub-region are composed, then one 3-D facial caricature can be generated.

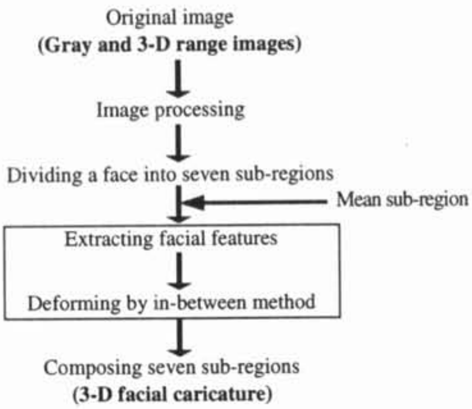


Fig.1 Diagram for generating 3-D facial caricature.

3. Rectangle Regions of Facial Parts

Basing on the fact that the highest point of the face of the range image becomes the point of the top of the nose, we propose the following algorithm to extract the respective rectangle regions for nose, mouth, and so on in this chapter.

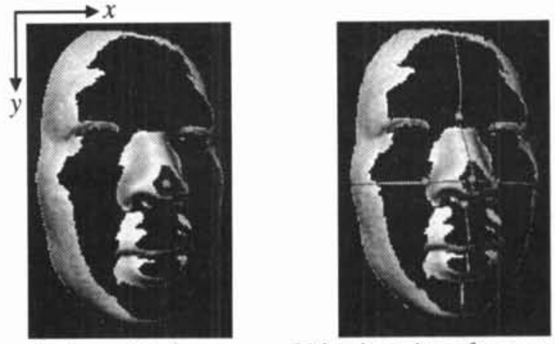
(1) Algorithm to extract rectangle nose region

In this algorithm, positive values for x and y are measured to the right on the x-axis and downward on the y-axis, respectively. $f^{(r)}=\{f^{(r)}_{xy} | 1 \leq x \leq 256, 1 \leq y \leq 240\}$ denotes face range image, and the maximum $f^{(r)}_{max}$ is calculated as $f^{(r)}_{max} = \max(f^{(r)}_{xy})$. The maximam point $P(x_{max}, y_{max})$ is extracted as the peak of the nose. Investigating the range data around $P(x_{max}, y_{max})$, the rectangle region of the nose is extracted by means of the horizontal and vertical profiles. Precisely investigating the curvature of the profile around the point $P(x_{max}, y_{max})$, we extract inflection points$(x_{max}, y_t^{(T)})$ $(t=1,2,3)$, $(x_{max}, y_b^{(B)})$ $(b=1,2,..,7)$. At that time, 2 horizontal lines to pass through the first inflection points $y_{(T,n)}=y_1^{(T)}$, $y_{(B,n)}=y_1^{(B)}$ are considered as the boundaries where the nose region is vertically sandwiched.

The gradient (Sobel operator) is calculated from a face range image $f^{(r)}$ as shown in **Figure 2(a)**. From this gradient image, x-coordinates $x_{(L,n)}$ and $x_{(R,n)}$ which are more than a threshold and are sandwiching horizontally around the peak of the nose are extracted. These coordinates give the left and right sides of the nose region (**Figure 2(b)**). Consequently, the nose region is obtained as the region $\{(x,y) | x_{(L,n)} \leq x \leq x_{(R,n)}, y_{(T,n)} \leq y \leq y_{(B,n)}\}$. An example is shown in **Figure 3(a)**.

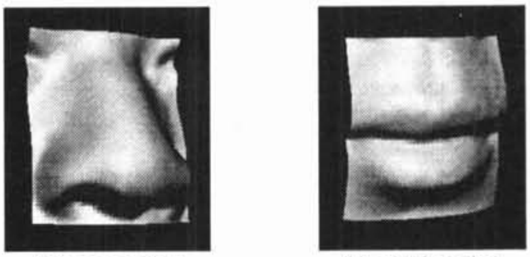
(2) Algorithm to extract rectangle mouth region

The boundaries where the mouth region is vertically sandwiched are defined by $y_{(T,m)}=y_1^{(B)}$ and $y_{(B,m)}=y_5^{(B)}$. The gradient of a range image in a direction of x-axis at $y_{(M,m)}$ is scanned where $y_{(M,m)}=y_3^{(B)}$. A pair of the x-coordinates $x_{(L,m)}$ and $x_{(R,m)}$ are extracted to sandwich a region horizontally. The mouth region is decided as $\{(x,y) | x_{(L,m)} \leq x \leq x_{(R,m)}, y_{(T,m)} \leq y \leq y_{(B,m)}\}$. This example is shown in **Figure 3(b)**.



(a) top point of nose (b) border points of nose region

Fig.2 An example of boundaries extracted as a rectangle region.



(a) nose region (b) mouth region

Fig.3 Examples of the rectangle regions, nose and mouth.

4. 3-D Caricature Generation

4.1 mean face

In order to generate 3-D facial caricature, it is necessary to generate a 3-D mean face as the reference with which 3-D individuality features are extracted. The mean face of the range image is calculated respectively for each sub-region in which the respective facial part is included. The whole mean face is composed by seven mean faces. The following procedure is proposed to generate the mean face mainly by using Affine transform.

Step 1: One sub-region i is selected $(i=1,2,..,7)$.

Step 2: The size of the rectangle sub-region is corresponded to that of the mean sub-region by Affine transform.

Step 3: After normalization of the region, the range data are averaged.

Step 4: Each mean sub-regions (i=1,2,..,7) are collected as one whole face, and one 3-D mean face is generated.

An example of the 3-D mean face which was provided by 4 range images is shown in **Figure 4**.

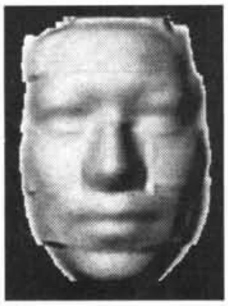


Fig.4 An example of 3-D mean face.

4.2 deformation for 3-D caricaturing

Let the 3-D mean face be S, the original 3-D face image be P, and parameter of an exaggeration weight for deformation be b. Basically, we think that the 3-D facial caricature Q can be generated by

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

However, not only the shape but also the location and range informations of the facial parts are to be exaggerated, we propose the following procedure for deformation.

The deformation procedure is as follows. Here, we denote the seven sub-regions $\{(x,y)|\ x_{(L,i)} \leq x \leq x_{(R,i)},\ y_{(T,i)} \leq y \leq y_{(B,i)}\}$ (i=1,2,..,7) that are given in chapter 3. And, it is necessary to normalize the face in advance in order to exaggerate this features by comparing the mean face. First, we decided 3 points, the nose peak (x_1, y_1), right (x_2, y_2) and left (x_3, y_3) end points of the mouth, as the reference points for the normalization. **Figure 5** shows an example of the reference points automatically extracted. By using these 3 reference points, the respective face is normalized in such a way that the point (x_1, y_1) becomes coincident to (x_0, y_0) specified in advance, and that the line, connected two end points (x_2, y_2) and (x_3, y_3) of the mouth, become constant and level.

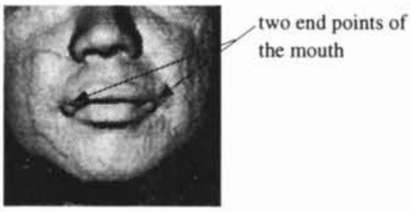


Fig.5 Feature points for normalization.

Step 1: Facial features are exaggerated by

$$\begin{aligned} x_{(L,i)}^{(Q)} &= x_{(L,i)}^{(P)} + b(x_{(L,i)}^{(P)} - x_{(L,i)}^{(S)}) \\ y_{(T,i)}^{(Q)} &= y_{(T,i)}^{(P)} + b(y_{(T,i)}^{(P)} - y_{(T,i)}^{(S)}) \\ x_{(R,i)}^{(Q)} &= x_{(R,i)}^{(P)} + b(x_{(R,i)}^{(P)} - x_{(R,i)}^{(S)}) \\ y_{(B,i)}^{(Q)} &= y_{(B,i)}^{(P)} + b(y_{(B,i)}^{(P)} - y_{(B,i)}^{(S)}) \end{aligned} \qquad (2)$$

for corresponding the left-upper point $(x_{(L,i)}^{(P)}, y_{(T,i)}^{(P)})$ and the right-lower point $(x_{(R,i)}^{(P)}, y_{(B,i)}^{(P)})$ of an input face P (**Figure 6(a)**) to left-upper point $(x_{(L,i)}^{(S)}, y_{(T,i)}^{(S)})$ and the right-lower point $(x_{(R,i)}^{(S)}, y_{(B,i)}^{(S)})$ of a mean face S. The left-upper point $(x_{(L,i)}^{(Q)}, y_{(T,i)}^{(Q)})$ and the right-lower point $(x_{(R,i)}^{(Q)}, y_{(B,i)}^{(Q)})$ of a facial caricature Q are calculated.

Step 2: By means of the range value with an input face P and the mean face S, a range data of a facial caricature Q is calculated by

$$z_{i(xi,yi)}^{(Q)} = z_{i(xi,yi)}^{(P)} + b(z_{i(xi,yi)}^{(P)} - z_{i(xi,yi)}^{(S)}). \qquad (3)$$

Step 3: Every facial part (i=1,2,..,7) is calculated by step 1 and step 2.

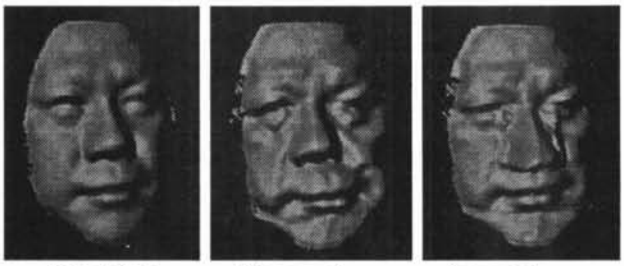
Step 4: Each facial part (i=0,1,2,..,7) is collected, and one 3-D facial caricature is generated. It is shown in **Figure 6(b)**.

Step 5: Finally, 3-D facial caricature is processed by smoothing filter.

Additionally, this method can exaggerate exclusively one facial part as shown in **Figure 6(c)**. This can be expressed by

$$Q_i = P_i + b\alpha_i(P_i - S_i) \qquad (4)$$

where α_i is exaggeration weight. This result was a typical one where the nose is exclusively exaggerated (α_4=1.5).



(a) original (b) normal deformation (c) partial deformation

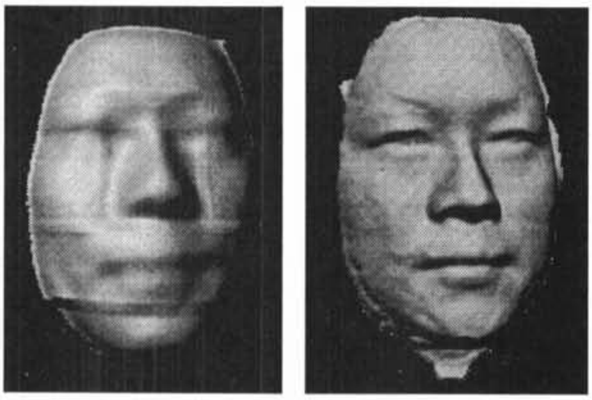
Fig.6 An example of 3-D facial caricature.

5. Experiments and Considerations

We compared the proposed simple method with a reference method. The reference method is the common method in which the faces are corresponded by the triangular patches which are generated on the contour edges of the facial parts.

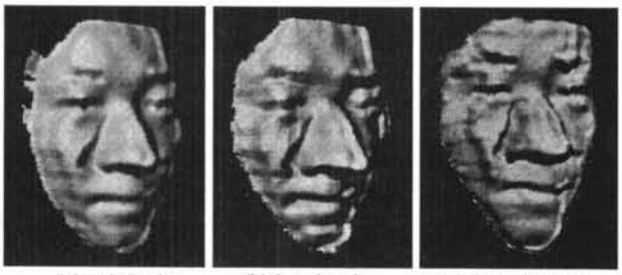
Figure 7(a) and **(b)** show the mean faces which are calculated respectively by the proposed and the reference methods. The number of the correspondence points was 205 in the reference method and one of the proposed method was 14. Therefore, it was known that no fatal degradations in the mean face appeared even when more than 90% reduction of the correspondence points. **Figure 8** demonstrates the 3-D facial caricatures to show the feasibility of the proposed mean face.

Figure 8(a) is an original 3-D range image, and **(b)** and **(c)** are the 3-D facial caricatures generated by using mean faces given by the proposed and the reference methods, respectively. We can confirm from these experiments that the individuality features of the person, the first author of this paper, are successfully exaggerated in his tough nose, tight lips, and sharp jaw both by the proposed and the reference methods.



(a) by simple method (b) by reference method

Fig.7 An example of 3-D mean face.



(a) original (b) by simple method (c) by reference method

Fig.8 An example of 3-D facial caricature.

6. Conclusions

In this paper, we proposed a mechanism to generate facial caricature by using face range image and verified to generate the 3-D facial caricatures. In this experiment, the following items were confirmed.

(1) Basically the proposed method was able to generate 3-D facial caricature, even when more than 90% reduction of the correspondence points is introduced.

(2) On the other hand, the mean face of the proposed method is rather degraded. Simultaneously, this degradation did not yield no fatal degradation in facial caricaturing.

(3) Changing independently the exaggeration weight in each facial part provides several interesting results, as shown in **Figure 6(c)**.

We can use this method as the coming caricaturing tool. Therefore the tool can be used for many thing. In the future, we would like to improve a processing speed and would like to apply this method to the motion features of the face.

Ackowledgement

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