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3 次元顔モデルの美男美女化技法

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魅力的な外見は一般に好まれる傾向にあるため，通常，人々は自分をよりよく見せようとする傾向がある．我々は，顔の個人的特徴をできるだけ残しつつ，その美しさを向上させるために，顔データを変形する手法を提案する．顔の魅力に関する既存研究を調査した結果，小さい，かつ／または，アンバランスな目と，突出した口を変形対象とする．変形は，3 次元の顔データに対して適用される．用いる顔データには，顔の部分（目や唇など）に分類された特徴点が含まれている．変形は，特徴点の移動により実現し，その移動は特徴点を囲む計測サンプル点の座標にも反映される．提案手法を適用して変形した 8 人分の顔データを用いて，アンケート調査を行った．その結果，提案手法が個人的特徴を残しつつ美男美女化することに有効であることが確認された．

キーワード: 顔の美しさ，美男美女化，3 次元変形

Modification Technique of 3D Facial Models for Improving Beauty

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People usually try to show themselves attractively, since attractive looks are generally preferred. We propose a new method for modifying facial data in order to improve facial beauty while retaining the original features as much as possible. Based on investigations into related work of facial attractiveness, the targets for modification in our method are small and/or unbalanced eyes, and a projecting mouth. We apply these modifications to 3D facial data sets. The data sets have the characteristic points that are classified into facial parts. The coordinates of the characteristic points are moved, the modification affects the raw data points surrounding the characteristic points, and a modified face is represented. We evaluated the modified faces of eight people with a questionnaire survey. As a result, we confirmed our method was useful for increasing the beauty of facial data while retaining the original features as much as possible.

Keywords: facial beauty, facial beautification, 3D modification

1 Introduction

People have been doing facial research for thousands of years. For more than 2,000 years, people have tried to establish the principles that underlie all judgments of beauty [1, 2, 15, 22]. Although we do not yet have any established principle, anthropological research makes it clear that all over the world, people seem to agree on what faces are considered beautiful [1, 4, 10, 21, 22]. One facial research topic in computer graphics is the modification of facial data for a specific purpose. There are systems proposed that can make materials for psychological experiments [7, 8, 11, 14]. Although new facial images/models with different features are generated from facial data inputted to the systems, the systems do not deal with the modifications of facial images/models while retaining the original features. Other outcomes are cosmetic surgery simulations, which are widely used at cosmetic surgery clinics. In such a simulation, there is no restriction for retaining personal natural characteristics as much as possible.

As a typical work in generating portraits, Koshimizu et al. have proposed a technique for modifying facial data [12]. In their method, the characteristics of each person are defined as the dif-

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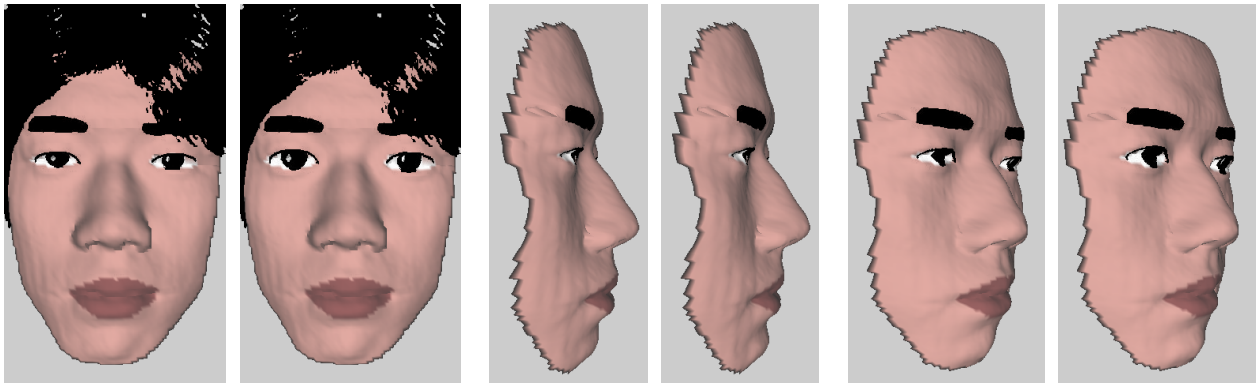


(a) (b) (c) (d) (e) (f)

Figure 1: Original and modified facial models: (a) the original face in full face; (b) a face with modified eyes in full face; (c) the original face in profile; (d) a face with a modified mouth in profile; (e) the original face in half-right profile; and (f) a face with modified eyes and a mouth in half-right profile.

ferences between an average face and each person's face. The modifications are performed by emphasizing the differences. They applied this technique to both of 2D and 3D facial data. Although the method can generate attractive representations of facial data, the result does not always satisfy the model himself/herself. It is because he/she does not always consider the emphasized differences as positive. Gooch et al. proposed a modification method that was not dependent on any average data [6]. In their work, although the result illustrations were useful for recognizing a person, facial beauty was not considered.

The face plays an important role in human communication. Attractive looks are generally preferred. Therefore, we tend to try to show ourselves at our best. If there was a method of modification that could improve our appearance and still retain our features, it could be used for portraits, avatars in virtual environments, etc.

We propose a new modification technique for improving facial beauty that is able to retain original features as much as possible. We first reported the results of the proposed technique in a previous paper [16]. According to investigations into facial attractiveness, the targets of modification in our method are small and/or unbalanced eyes, and a projecting mouth. The modification process is based on the 3D facial data sets that are defined in the system of 3D facial caricature [20]. In the data sets, the characteristic points are classified into facial parts (e.g. eye, mouth, nose, etc.). The concept of our method is to make beautiful faces by making only small modifications. This is because small modifications retain the original features. Characteristic points in relation to the eyes and mouth are moved at a certain rate, the modification affects raw data points surrounding the characteristic points, and then a modified face is represented, as shown in Figure 1. This kind of modification was applied to the facial data of fifteen people. As a result, we were able to confirm the validity of the proposed method.

2 What are the Factors of Facial Beauty?

It is generally thought that evaluating beauty is difficult, because each mind perceives beauty differently. Cross-cultural studies, however, have confirmed that all over the world, people seem to agree on which faces are considered beautiful, whether they are judging men or women, and people from their own or different racial backgrounds. Some studies have confirmed that women are generally regarded as beautiful if they have smooth skin, large eyes, and plump lips [1, 4, 21, 22]. These features are also valued in judging babies' beauty. Concerning men, most people tend to be attracted to male faces with large eyes [1, 4, 10, 21, 22].

The line tangent from the tip of the nose to the

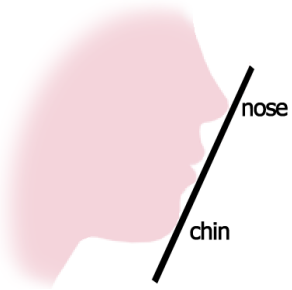


Figure 2: Ricketts' aesthetic line (E-line).

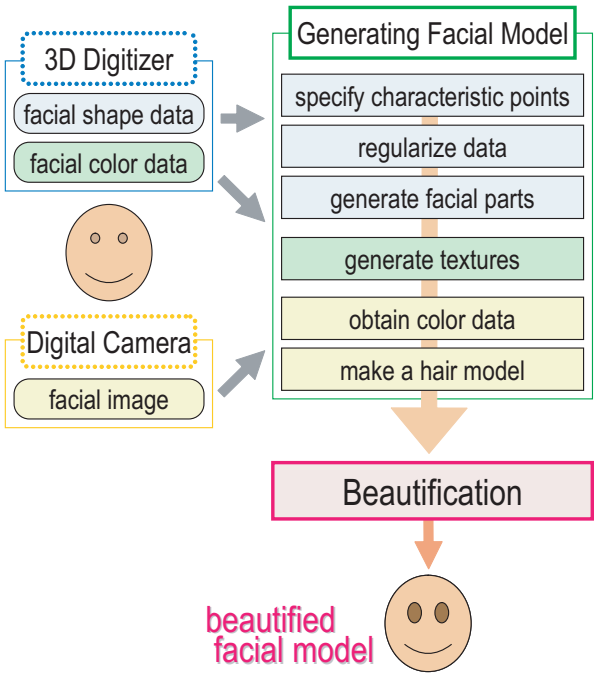
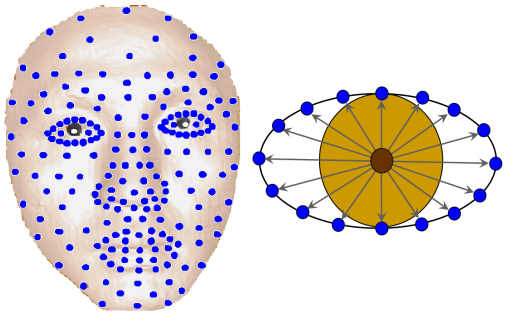


Figure 3: Outline of preliminary processing for proposed beautification methods.

end of the chin was termed *aesthetic line/plane (E-line/E-plane)* by Robert Ricketts [17]. The E-line is illustrated in Figure 2. In 1954, he developed a beauty standard based on the E-line principle that the tips of lips did not protrude from the E-line. The details of this standard are different for each race. For the Japanese, it is said that the tip of the lower lip should be around the E-line [15]. In addition to the E-line, there are several linear profile measurements: the *S-line* by Steiner [18]; the *H-line* by Holdaway [9]; the *Profile line and Z angle* by Merrifield [13]; the *B-line* by Burstone [3]; and the



(a) (b)

Figure 4: Definitions in the 3D facial data set [20]: (a) arrangement of the characteristic points; and (b) example of the shape vectors.

S'-line by Sushner [19]. The reason we chose the E-line is that extracting the E-line is easier than the other indexes. Moreover, the E-line is well-known in Japan and the ideal range of the distance between the mouth and the E-line for the Japanese has been researched.

From a biological view point, it has been confirmed that symmetrical looks are more sexually attractive [1, 22]. Because symmetry suggests that there is little harmful mutation, animals have an acknowledgment system that makes them feel sexually attracted to symmetry. However, a very attractive human face is not completely symmetrical [1, 22].

Age is also an important element of beauty. Although there are many standards of beauty, in the first step of our research we target large, balanced eyes and an unprojecting mouth. We currently use the same standard of beauty for both men and women. This is because large eyes and symmetrical looks are attractive in both men and women. In addition, there are no different standards for the position of lower lip between the sexes.

3 Target Modification Data

We use the 3D facial data set defined in the system by Takemoto et al. [20] as the target data of modification. Figure 3 shows the outline of the data set generation. The data sets consist of raw data measured with a non-contact 3D digitizer, and image data taken with a digital camera. Each data

set is composed of the following: raw data measured with a non-contact 3D digitizer; characteristic points (196 points as shown in Figure 4(a)); classifying information of the characteristic points; vectors from the center of each facial part to all the characteristic points belonging to the part (shape vectors as shown in Figure 4(b)); vectors from the center of the face to the center of each facial part (position vectors); the color values of the skin and the lips; the texture of eyebrows and eyes; and the texture of the hair. The characteristic points are defined in order to generate a 3D caricature. The position of each characteristic point is hand specified using a pointing device. As mentioned below, parts of these characteristic points are used in beautification. Since these points are basically easy to specify, no error reductions are currently applied to the specified points. During the beautification process, the coordinates of the characteristic points are modified. After the modification of all characteristic points, the raw data points are modified in order to make the modification valid not only for the characteristic points but also the related raw data points. Finally a modified face is represented.

4 Facial Beautification

4.1 Enlarging the eyes

When enlarging the eyes, we use the characteristic points and the shape vectors of the eyes. An eye's characteristic point P_k is moved to the point P'_k using the shape vector V_k by the following equation:

$$P'_k = P_k + V_k \times rate \times rate_{xy}, \qquad (1)$$

where $rate$ is the enlarging rate that is inputted by a user and $rate_{xy}$ is the weight depending on the direction of the width or height. The reason we use $rate_{xy}$ is that the total balance of the face becomes strange if the eyes are enlarged and the aspect ratio is still retained. We experimentally set the $rate_{xy}$ as the ratio of width (x) to height (y) eleven thirteenth. The coordinates of the depth axis do not change. This is because changing the depth information is unimportant in relation to the size of eyes in full face and there is no standard for sharply-chiseled features. Figure 5 shows an example of enlarged eyes. In Figure 5(b), the width of eyes is 1.1 times wider than original width, and the height is 1.3 times higher than the original height. The weight $rate_{xy}$ seems appropriate.

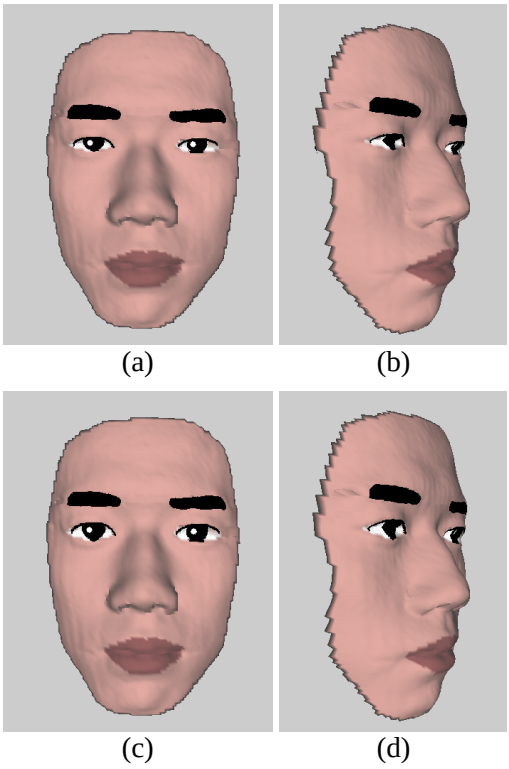


Figure 5: Facial model with enlarged eyes: (a) and (b) the original eyes; and (c) and (d) enlarged eyes.

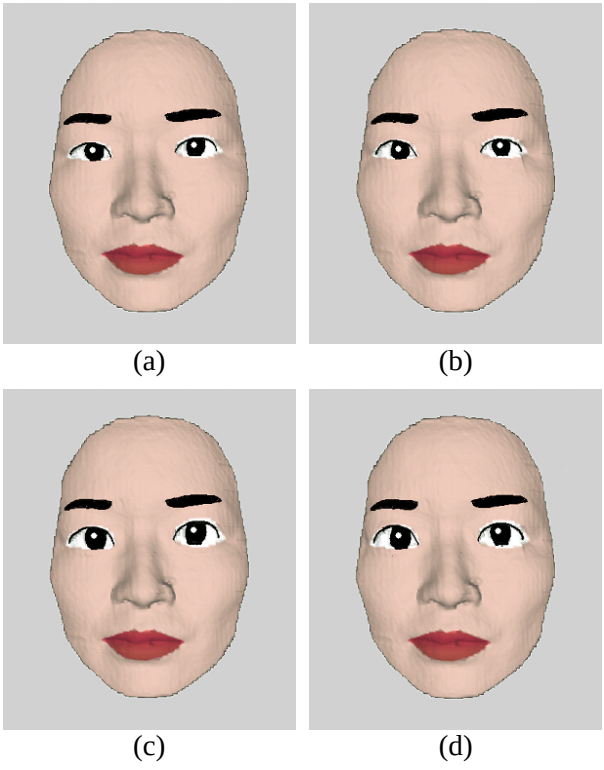
4.2 Balancing the eyes

By reducing differences in the shape and position of each eye, the eyes become balanced. In order to retain the original features as much as possible, both eyes are modified to an average shape and position instead of reversing and exchanging one eye for the original one. After this, the coordinates of the depth axis are not changed again. Therefore, the eyes do not become exactly identical.

A new shape vector V'_k is calculated using the right eye's shape vector V_{k_r} and the left eye's shape vector V_{k_l} with the following equation:

$$V'_k = \frac{V_{k_r} + V_{k_l}}{2}, \qquad (2)$$

where the coordinates of the depth axis are not changed again. The unchanged depth value produces eyes that are not totally even. This means



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

Figure 6: Facial model with balanced eyes: (a) the original eyes; (b) balanced eyes; (c) enlarged eyes; and (d) enlarged and balanced eyes.

that the original characteristics are retained somewhat in spite of balancing. The characteristic points corresponding to the modified shape vectors are updated. Figure 6 shows some examples of balanced eyes. The effect is obvious in the model with enlarged and balanced eyes.

4.3 Reducing mouth projection

To modify the characteristic points in and around mouth, first, the E-plane, which is defined by the point of the nose tip and the line which goes through the nose tip and one of chin points, is calculated. The E-plane is parallel to the horizontal axis, shown as $Z = f(y)$ in Figure 7.

To reduce mouth projection, we can use several methods. The simplest way is to pull the mouth back without making any change to the lip shape. In this case, the facial features in full face are not drastically changed. Sliding the mouth vertically or scaling down the mouth also makes the mouth projectless or not at all. This method causes facial impression changes in the whole face and we could not find any standards among them. As we are trying to retain the original features as much as possible, we simply pull the mouth back.

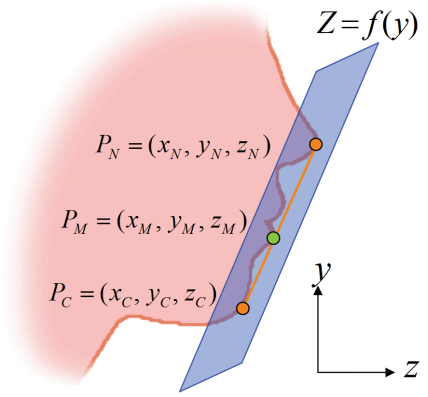
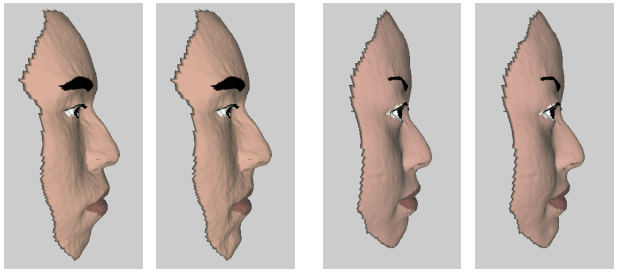


Figure 7: E-plane for reducing mouth projection.



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

Figure 8: Facial models with an unprojecting mouth: (a) and (c) the original mouth; and (b) and (d) an unprojecting mouth.

When the depth coordinates z_M of the lower lip are farther than the E-plane, the characteristic point of the tip of the lower lip is pulled back to the E-plane using the following equation:

$$z'_M = \frac{z_N - z_C}{y_N - y_C}(y_M - y_N) + z_C, \qquad (3)$$

where $P_M = (x_M, y_M, z_M)$ is the coordinate of the tip of the lower lip, $P'_M = (x'_M, y'_M, z'_M)$ is the coordinate of the moved tip of the lower lip, $P_N = (x_N, y_N, z_N)$ is the coordinate of the nose tip, and $P_C = (x_C, y_C, z_C)$ is the coordinate of the chin tip. All characteristic points of the lip are also moved in the same direction and at the same distance. In order to avoid distortion, the surrounding characteristic points are also moved with weight according

(a) (b)

Figure 9: Examples of facial models using the original photograph: (a) the original face; and (b) a beautified face.

(a) (b)

Figure 10: Examples of facial models using a illustration style image: (a) the original face; and (b) a beautified face.

to the distance from the mouth. Figure 8 shows examples of nonprojecting mouths. In the modified models, the mouth and surrounding areas are drawn in, but the original characteristics are still retained.

5 Experimental Results

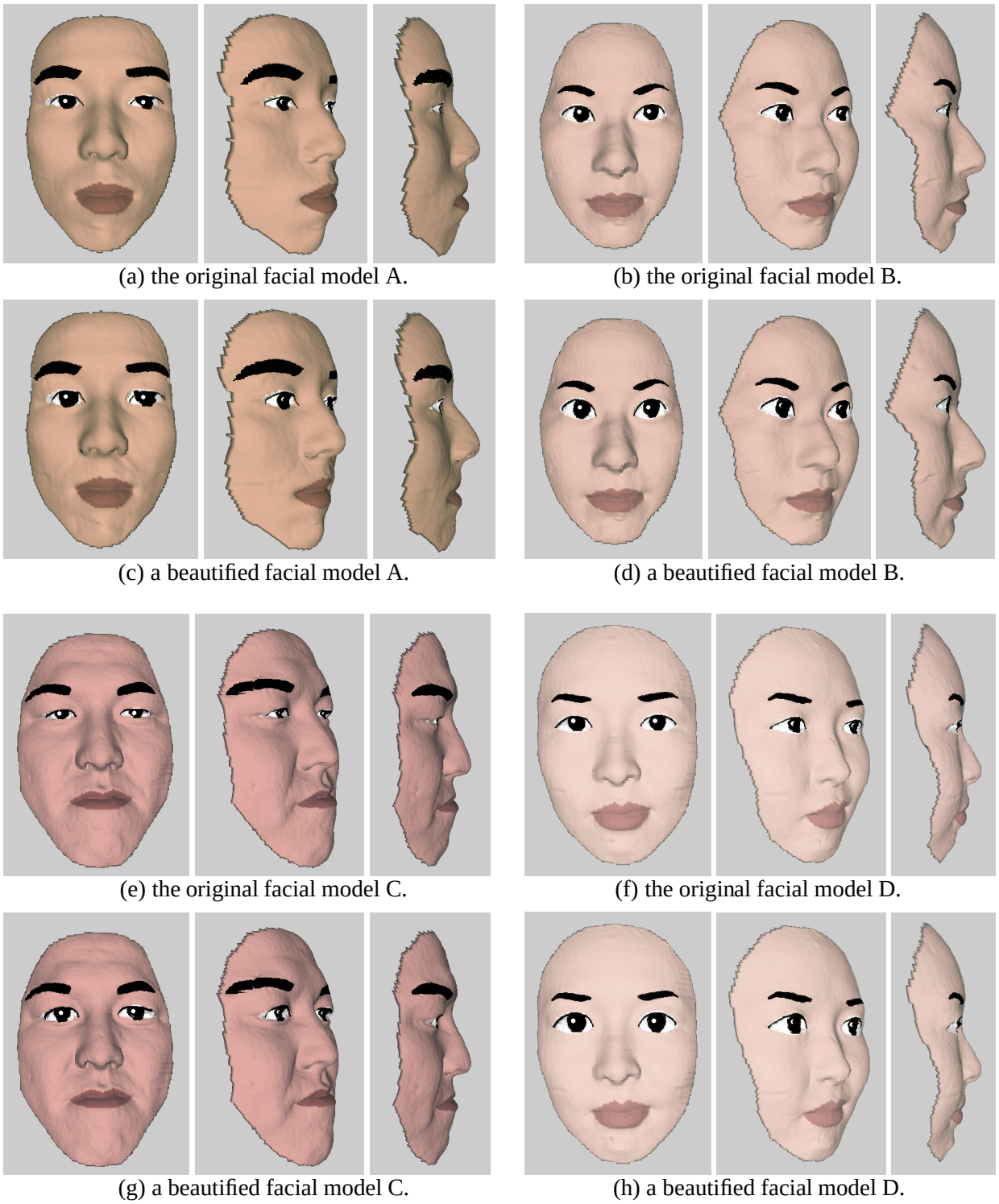
We experimented with our method on the facial data of fifteen people. In addition to Figures 1, 5, 6, and 8, the beautified facial models are shown in Figures 9, 10, and 11.

The differences between the mapped images are shown in Figures 9 and 10. Figure 9 shows examples of an original and beautified facial model using original color data taken with non-contact 3D digitizer. Figure 10 shows examples using the color values of the skin and the lips, and texture images of the eyebrows and eyes, similar to the previous figures. Although a uniform skin color makes the artificial wrinkles around the corners of the eyes prominent, we used these illustration style images for the questionnaire since it is easy to recognize the differences between the original and beautified models.

In our experiment, there were twenty two subjects; 11 men and 11 women. Their ages ranged from fifteen to forty years old. The proposed method is designed according to the Japanese criterion of facial beauty. Therefore, we carried out a questionnaire survey of Japanese people, who rated the beautified models. The subjects had never met the facial models.

We used eight Japanese people in their twenties (four men and four women) as facial models for the questionnaire. Each model has some of the following features: model No. 1 (m) has narrow eyes. His mouth projects a little; model No. 2 (m) has slightly narrow eyes. His mouth projects; model No. 3 (m) has slightly small eyes. His mouth projects a little; model No. 4 (m) has small eyes. His mandibular is slightly augmentative; model No. 5 (w) has slightly small and unbalanced eyes; model No. 6 (w)'s mouth projects a little; model No. 7 (w) has large eyes. Her mouth projects a little; and model No. 8 (w) has slightly large eyes. Her mouth projects a little. For each model, we generated five patterns: (A) the original model; (B) a model with enlarged eyes; (C) a model with balanced eyes; (D) a model with an unprojecting mouth; and (E) a beautified model (that has enlarged and balanced eyes and an unprojecting mouth). In enlarging the eyes, the width of eyes is 1.1 times as wide as the original width, and the height is 1.3 times as high as the original height in models Nos. 1-6, and 8. In model No. 7, the width of eyes is 1.05 times as wide and the height is 1.15 times as high. We printed out full color pictures of the models. The full face, the face in half-right profile, and the face in full profile were shown in one line as shown in Figure 11. The size of printed faces was almost 4 cm in height.

In the first question, we showed four sheets on which the images (A) and (E) of each model were printed. Two model's faces were printed on one



(a) the original facial model A.
(b) the original facial model B.
(c) a beautified facial model A.
(d) a beautified facial model B.
(e) the original facial model C.
(f) the original facial model D.
(g) a beautified facial model C.
(h) a beautified facial model D.

Figure 11: Examples of original and beautified facial models used for the questionnaire survey.

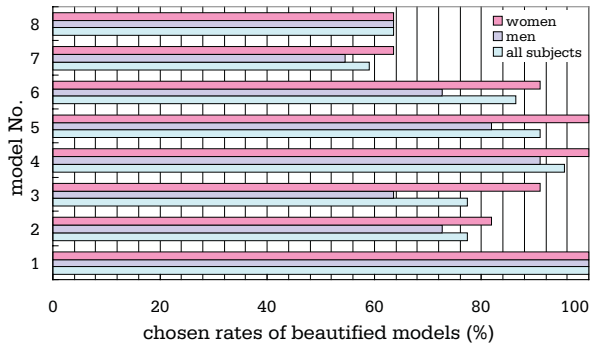


Figure 12: Results of the first question. The chosen rates of beautified models and not original models. Model Nos. 1- 4 are men and the rest are women.

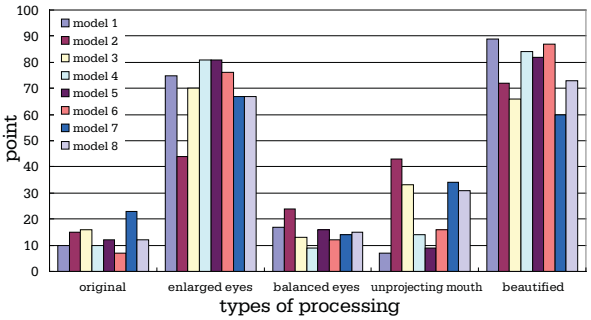


Figure 13: Results of the second question. Total ranking points. The correspondence of a model No. with a person is same as the first question (Figure 12).

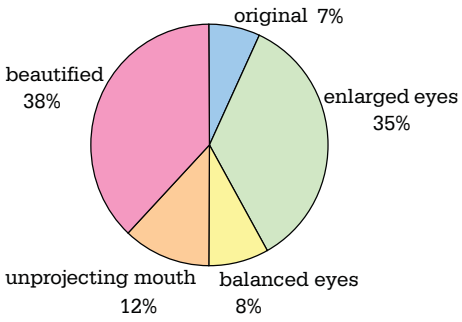


Figure 14: Overall ratio of the answers to the second question. Ratio of types in the chosen models.

sheet and the type-order was random. From the two examples of each model, the subjects chose the more beautiful one. Figure 12 shows the results. The rates of beautified models chosen were higher than the rates of the original models chosen. The rates of beautified models chosen by women were higher than those chosen by men. There were two models whose original model was chosen at rates similar to the beautified models. Those two models had large eyes originally. This indicates that the eyes of those two models were already suitable for their faces.

In the second question, we showed eight sheets where all images (A)-(E) of each model were printed on each sheet. The order of images was random. The subjects chose the three highest ranking images. We assigned five points to the first ranking, three points to the second, and one point to the third. Figure 13 shows the total points. Models with enlarged eyes and the beautified models were chosen first at the almost same rates. In the rest, models with an unprojecting mouth were chosen more than others. There was a model that got high points in the image showing an unprojecting mouth that was the same as the model with enlarged eyes. Originally that model had a projecting mouth. The original mouths of the other models projected a little and the effect of making the mouth to not project was not prominent. The result indicates that the unprojecting modification worked well on the model when the original model had a conspicuous projecting mouth.

Figure 14 shows the overall ratio of answers to the second question. The beautification process is first, the enlarging process is second, and the unprojecting process is third. The Japanese have been focusing on the beauty of the full face for long time [15]. In full face, the size of eyes stands out from a unprojecting mouth. Our purpose is to modify facial data in order to improve facial beauty while maintaining the original features as much as possible. From this view point, the rate of enlarging the eyes was somewhat unsuitable. Since eyes are important for recognizing a person's face [5], the best rate for unprominent beauty should be investigated. Concerning the balanced eyes and an unprojecting mouth, we have to collect facial data and conduct our investigation again since we had only one model who had unbalanced eyes and one model who had an obviously projecting mouth. In addi-

tion, we did not modify the mandibular augmentation, because the difference between the upper and lower jaws had not been considered in our method yet. Modifications to reduce mouth projection, including the factor of mandibular augmentation, may be similar to cosmetic surgery simulations. For better results, this should be considered.

6 Conclusions

We proposed a method to beautify facial 3D models. The targets of modification in our method were small and/or unbalanced eyes, and a projecting mouth. We investigated the effectiveness of our method and confirmed that the proposed method was useful for faces that did not originally possess specifically beautiful factors.

We decided that the modification had to retain the original feature as much as possible in order to assure the recognizability of a person's face. Our approach can achieve this. There is a trade-off between recognizability and beautification. As a future work, we are going to find the best range of each parameter value that can maintain the balance between recognizability and beautification. We would like to integrate the other elements of facial beauty into the current technique, for example, the smoothness and color of the skin, especially for 3D facial models that use the original photograph for mapping. These generated models will be useful for non-anonymous avatars in virtual environments and for materials for psychological experiments.

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