Received March 30, 2013; Accepted June 18, 2013

International Journal of Asia Digital Art&Design

Three-dimensional variable face model formation manufacture device based on face impression evaluation

Meng Jae Young
Faculty of Design, Kyushu University
m1004jylove@hotmail.com

Etsuo Genda
Faculty of Design, Kyushu University
genda@design.kyushu-u.ac.jp

Abstract

The authors have often experienced that impression extremely changes with slight deformation of profile and molding in the face modeling by 3DCG. Therefore, in this paper, the authors aim at clarifying how variation of the facial structure affects that of psychological impression and at proposing modeling device by determining structure of various face impression. Impression evaluation with plane illustration and photos, which are two-dimensional images, have been studied by a number of researchers so far.

In this paper, facial 3D models were produced by direct operation on monitor. Digitizing each facial part enabled to have facial images deformed at will. Moreover, quantity of transformed location can be grasped as an advantage and it is a unique system on the premise of creation of a real 3D face model

Keywords: Face impression, Three dimension computer graphic, Facial modeling

1. Introduction

There have been a lot of past studies on face impression evaluation. In most of their studies, impression evaluation factors were derived by principal component analyses with some stimulus words for figures simply consisting of facial profile, eyebrow, eyes, nose and mouth by illustration and photos for which each expression was shot and their relationship with the parts were described. For example, Abe et al. (2008) related impression evaluation factors such as fresh by shape and placement of elements such as facial profile, eyes, eyebrow, nose and mouth, using features map determined beforehand [1] and Kaneko et al. studied a portrait development system by which eyebrow, eyes, nose, mouth and profile were transformed [2]. In this study, the authors produced a three-dimensional face for real expression and designed a system that newly forms a face based on impression factors. Here, we deal with positive face creation not with a face that is already made and aim at applying the technique to creation of new characters in CG production.

2. Method and Purpose of the Study

The purpose of this study is to understand the factors that determine face impression by evaluating face impression created using 3DCG, to examine the structural features of the face that influence these image evaluations, and to deduce the regularities of facial structure that provide these images. Furthermore, we create various facial models based on the regularities deduced from the basic model and demonstrate the process for proposing a template for CG facial modeling.

In this study, it was possible to quantify facial modeling by creating an experimental face using CG and recording and reproducing the parameters that changed on each part of the face.

The study method consisted of studying modern perceptions by referring to books, etc. relating to beauty and faces that were targeted at young people and collecting words and phrases relating to facial expressions from various magazines to identify image expression trends. Using these as references, we extracted stimulus words for use in the image evaluation experiment. Then, we conducted image evaluation on a 3DCG facial model using the SD method and, while determining the mutual semantic relationship of impression words by extracting the mutual correlation of impression words and factors relating to image evaluation, we also deduced the regularities from a surface anatomical perspective.

Furthermore, we created a template for facial modeling from the regularities deduced.

3. Image Evaluation Experiment for Facial Models

3.1. Study of Impression Words

In order to conduct a face impression evaluation, we studied impression words by referring to descriptions in magazines. Specifically, we focused on current facial expressions as expressed in magazines aimed at young people and extracted words from magazines that target women from their late teens to their forties.

We studied 12 magazines; 'Be-Story,' 'Bijin-Hyakka,' 'Lips,' 'SOUP,' 'JJ,' 'KERA,' 'SEDA,' 'MAQUIA,' STORY,' 'ar,' 'BITEKI,' and 'KATY.' We also studied six books relating to beauty or faces; 'CUTiE Make-up 2012,' 'Actress Make-up,' 'With: Super Simple Cute Make-up for Adults,' 'All about Make-up Method,' 'Reading Faces,' and 'Face Analysis.' Table 1 summarizes and classifies the impression words collected from the magazines and books. The 89 impression words were organized and classified into word groups; nouns, adjective verbs, adjectives, adverbs, and 'Other (multiple expressions).'

As a result of the classification of the impression words, we found that the magazines and books we studied, which were aimed at women, included many distinctive expressions to create a specific atmosphere.

Table 1: Impression Words Studied from Books relating to Beauty and Faces

Nouns	Adverbs
Baby face	Plump
Mature face	Soft
Mixed race face	Other (multiple expressions, etc.)
Childlike face	Elegant
Fox face	Smart image
Childish face	Refined
Lonely face	Cool beauty
Heroine face	Dependable face
Dolly face	Mature face
Princess face	Dependable-looking face
Elegant face	Haggard face
Romantic face	Grown-up cute
3-D face	Adult-like cute
Spring face	Refined and trim
Doll-like face	Cool and cute
Manly face	Healthy and bright
Pure face	Mature and gentle
Sweet face	Celebrity
Lady face	Beautiful, womanly face
Lion face	Kind and feminine
Adjective verbs	Soft and pretty
Healthy	Grown-up pretty
Neat and trim	Slightly girlie
Beautifu	Neat and sharp
Natural	Graceful image
Refined	Pampered baby face
Sexy	Innocent and loved face
Generous-hearted	Cool and enchanting
Cute	Soft, sweet face
Girlie	Mixed race celebrity-like face
Manish	Bare-faced fresh face
Formal	Orthodoxly popular face
Cold	Innocent and cute
Handsome	Urban beauty
Rich	Devilish doll face
Adjectives	Sexy and coquettish
Childish	Beautiful actress face
Sweet	Gentle and soft
Feminine	Cool, mature face
Cool	Self-assured adult image
Cute	Grown-up, smart image
Gentle	Sharp cool
Bright	Sharp and cool
Severe	Kind and gentle
Adult-like	
Childlike	
Gentle	

3.2. Creating a 3DCG Model

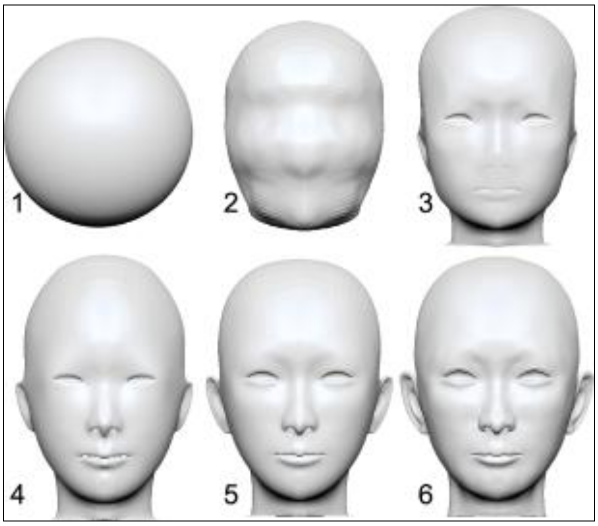

Fig.1: Creation Process for the Basic Model

We created a 3DCG facial model by expressing three-dimensional coordinate data as mesh data using a method for creating the face whereby the polygons in the sphere are increased while the positions of the parameters are changed for each part of the face. By using 3DCG to create the face, rather than a photograph or drawing, it was possible to quantify each part of the face and record the transformation process from the basic figure. It was also easier to capture the subject as an object using animation.

In the experiment, we created a total of 24 facial models by moving the positions of the parameters for each part of the face from the original basic facial model. The main parts of the face that we changed were the 'eyebrows, eyelids, the medial angle of the eye, auricular points, nostrils, the nasal point, the apex of the nose, the subnasal point, the mouth and the gnathion. Other changes were also made to the flesh on the cheeks and chin.

Fig.3 shows the 24 models created for the image evaluation experiment using the aforementioned method.

3.3. Image Evaluation Experiment for a 3DCG Facial Model

21 students aged between 18 and 26 (average age: 20.6) studying art engineering and having CG modeling experience were selected as the subjects of the experiment.

In regard to the image experiment conditions, the subjects were shown front-facing still images for 10 seconds each and then shown animated images of the faces rotated 45°to the left and 45°to the right for approximately 75 seconds on a 52 inch monitor. They completed a survey while viewing the images.

We referred to words and phrases selected from magazines, etc. and to academic journals and theses for the impression words used in this experiment. We also conducted a five-step evaluation using 18 pairs of these impression words together with their antonyms.

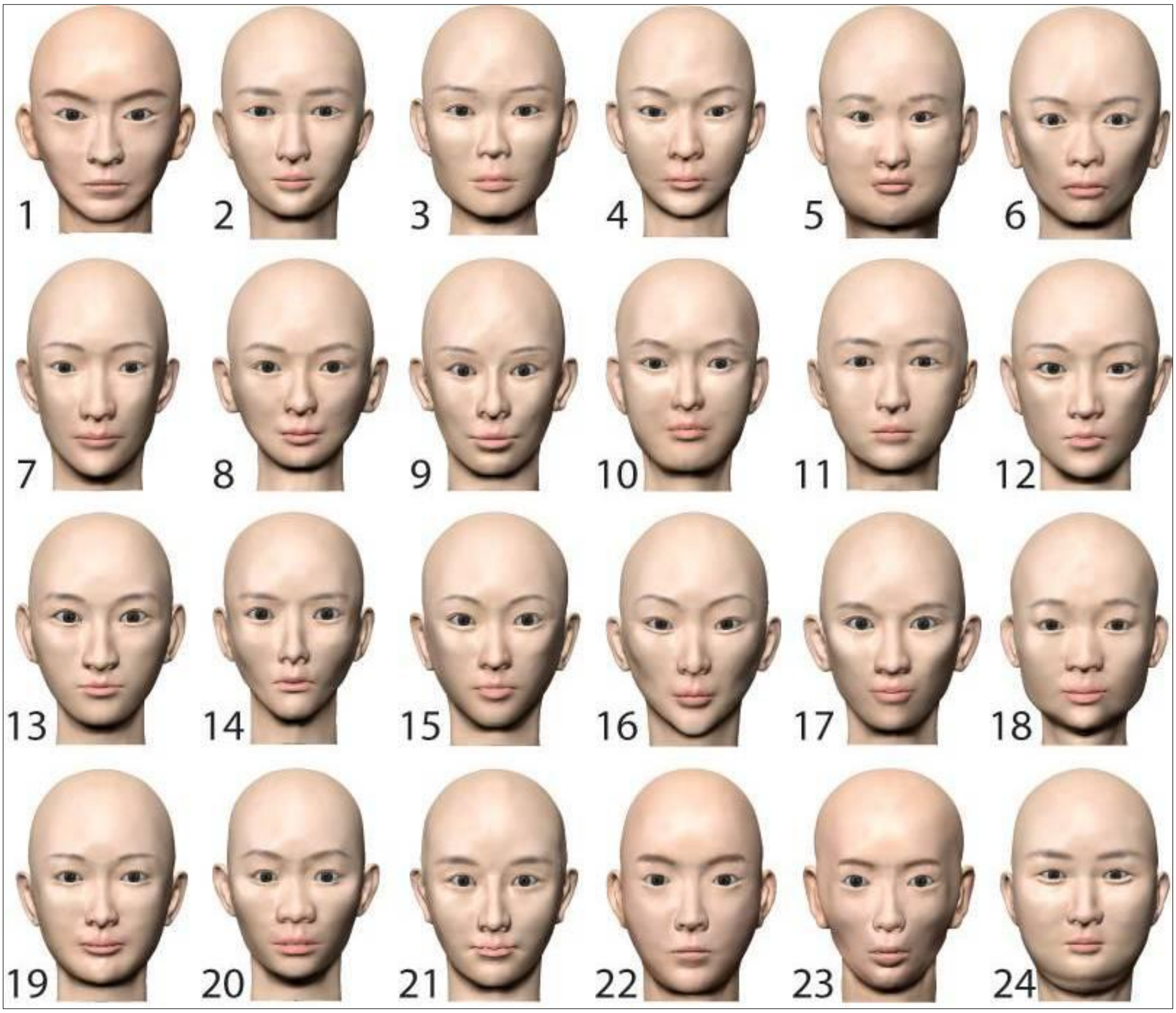

Fig.2: All Models for the Image Evaluation Experiment

3.4. Image Profile

For the image evaluation experiment, we graded the evaluation for each impression word for each model from 1 to 5 and output the average score. The impression words for which the average score was low or high represent the predominant image of that model. Fig.3 is a graph of the 24 models. Hereafter, we discuss the models that have a particularly strong image according to these results and describe the features of these models.

The features, 'large, fleshy face with a broad chin,' are apparent for images such as No.5, which was described by subjects as 'heavy, large, and vacant.'

The features 'upturned eyes, prominent cheekbones, narrow jaw and little flesh' are apparent for images such as No.16, which was described by subjects as 'individual and sharp.'

The features 'large eyes, thick lips, wide nostrils, thick eyebrows, and prominent cheekbones' are apparent for images such as No.17, which was described by subjects as 'healthy and dynamic. 'The features 'round eyes, no flesh, and thick lips' are apparent for images such as No.23, which was described by subjects as 'poor, unhealthy, and not cute.'

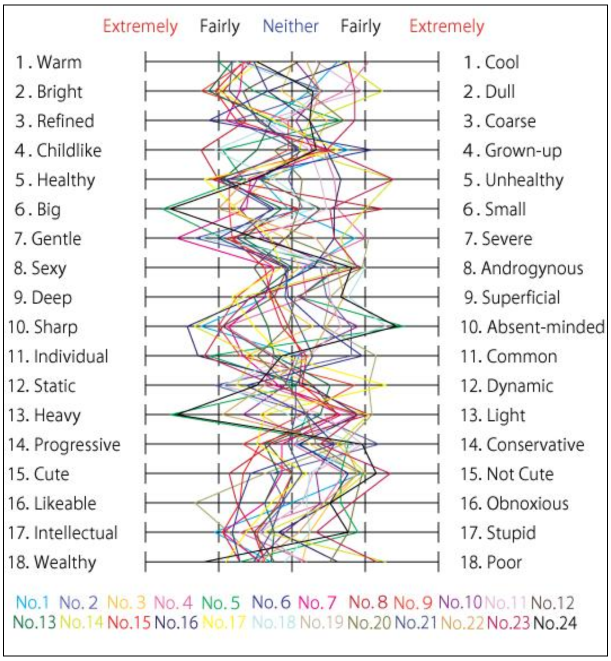

Fig.3: Graph of SD Profile Averages

In order to understand the correlation between impression words, we conducted correlation coefficient matrix analysis. Figure 4 is a diagram of the correlation coefficient matrix and shows the impression words that have a strong correlation.

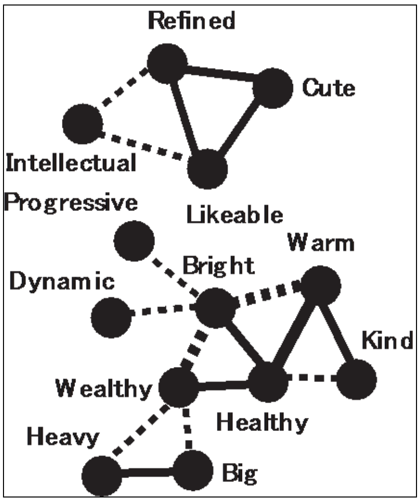

Fig.4: Correlation Coefficient Matrix for Impression Words

The impression words for which there is a strong correlation between the words and phrases according to the analysis can be grouped into three broad groups; a group relating to 'agreeable images' including such words as likeable, refined, and cute, a 'healthy and warm' group including such words as healthy, warm, wealthy, bright, and kind, and a 'large perception' group including words such as heavy and large. It is assumed that words and phrases with a strong correlation are perceived as words and phrases that conjure a similar image for the subjects.

Table 2: Principal Component Values for the Image Evaluation

	Principal component	Principal component	Principal component
1. Warm Cold	0. 802	−0. 442	−0. 114
2. Bright Dull	0. 841	0. 170	−0. 453
3. Refined Coarse	0. 776	0. 197	0. 566
4. Childlike Grown-up	0. 093	−0. 351	−0. 141
5. Healthy Unhealthy	0. 910	−0. 248	−0. 213
6. Large Small	0. 305	−0. 618	−0. 536
7. Kind Severe	0. 739	−0. 427	0. 114
8. Sexy Androgynous	0. 775	0. 519	−0. 067
9. Deep Superficial	0. 085	0. 786	−0. 455
10. Sharp Vacant	−0. 212	0. 942	−0. 114
11. Individual Common	−0. 506	0. 237	−0. 678
12. Static Dynamic	−0. 409	−0. 366	0. 792
13. Heavy Light	0. 138	−0. 830	−0. 408
14. Progressive Conservative	0. 416	0. 740	−0. 436
15. Cute Not cute	0. 878	0. 114	0. 315
16. Likeable Obnoxious	0. 906	0. 264	0. 278
17. Intellectual Stupid	0. 494	0. 658	0. 431
18. Wealthy Poor	0. 800	−0. 420	−0. 171
Contribution ratio	39. 8%	27. 3%	16. 5%

Next, we conducted principal component analysis for 1-3 factors. Table 2 shows the numerical values for the principal component coefficient matrix after varimax rotation.

We used the three principal components in Table 2. The contribution ratio was 39.8% for principal component 1, 27.3% for principal component 2, and 16.5% for principal component 3. The total contribution ratio was 83.6%.

The words 'healthy/unhealthy,' 'cute/not cute,' bright/dull,' 'warm/cold,' and 'wealthy/stupid' were evaluated highly with regards to principal component 1 and it was designated the 'likeability rating' axis.

The words 'sharp/vague,' 'heavy/light,' and 'deep/superficial' were evaluated highly with regards to principal component 2 and it was designated the 'weight perception' axis.

The words 'static/dynamic' and 'individual/common,' were evaluated highly with regards to principal component 3 and it was designated the 'power' axis.

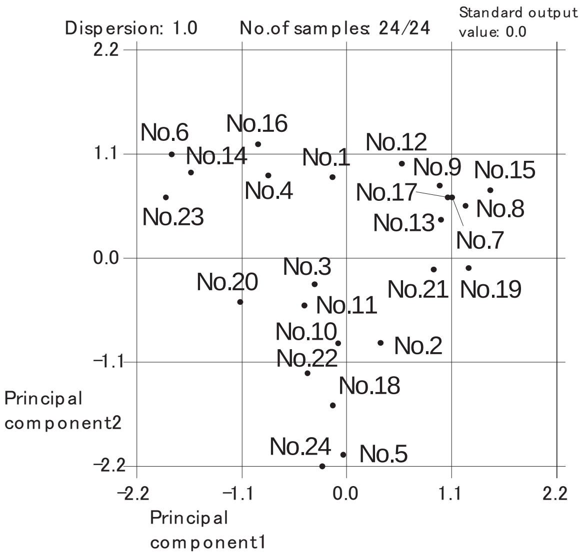

Fig.5: Score Dispersion Figure for Principal Components 1 & 2

Next, we identified the facial models that contributed significantly to each principal component and conducted analysis of structural features. Figures 5 and 6 show the principal component scores for the facial models.

The structural features apparent for principal component 1 include 'raised eyebrows,' 'prominent cheekbones,' 'emaciated,' and a 'triangular face shape.'

The structural features apparent for principal component 2 include 'size of the nostrils,' 'shape of the eyebrows,' 'prominent cheekbones,' 'flesh,' 'outline of the face,' and 'above and under the eyes.'

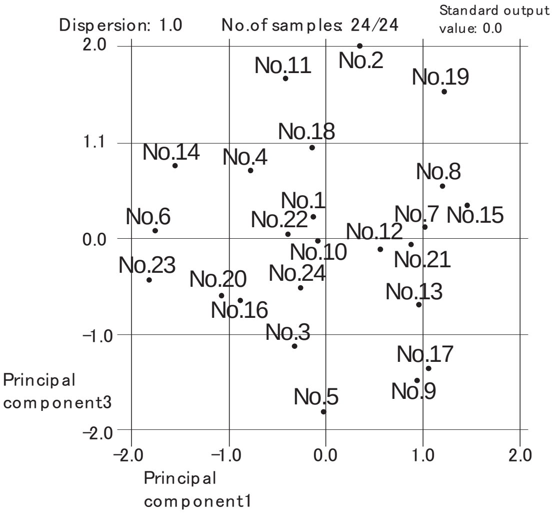

Fig.6: Score Dispersion Figure for Principal Components 1 & 3

The structural features apparent for principal component 3 include 'shape of the eyes,' 'thickness of the eyebrows,' 'shape of the eyebrows,' 'prominent cheekbones,' 'flesh,' 'outline of the face,' 'size of the nostrils,' and 'angle of the mouth.'

In order to conduct feature analysis of the numerical values for each part of the face, we measured various parts of the face. Fig.10 shows the parts of the face measured. The figure shows the item IDs as prescribed in the JIS (Japanese Industrial Standards) and the item IDs, numbers 01 to 10, that we assigned to parts of the face not in in the JIS standards.

The names of each part are defined by the JIS standards as, A3-Bitragion breadth, A8-Bigonial breadth, A10-Interocular breadth, A11-Biectocanthion breadth, A12-Nose breadth, A13-Mouth breadth, A14-Lip height, A16-Nose height, A17-Subnasale to gnathion, A18-Philtrum length, and A36-Total head height. Next, we defined the parts not specified in the JIS as 01-Glabella, 02-Eye breadth, 03-Eye height, 04-Angle of the outer corner of the eye, 05-Angle of the outer corners of both eyes from the lips, 06-Angle of the mouth, 07-Chin breadth, 08-Profile breadth, 09-Nose height, and 10-Mouth protrusion.

Next, we conducted feature analysis using the measurements for each principal component. It was found that, in the group where the principal component scores for principal component 1 were high, the subjects tended to be influenced by A3 (Bitragion breadth), A8 (Bigonial breadth), A13 (Mouth breadth), 06 (Angle of the mouth),

07 (Chin breadth), and 08 (Profile breadth). It was found that, in the group where the principal component scores for

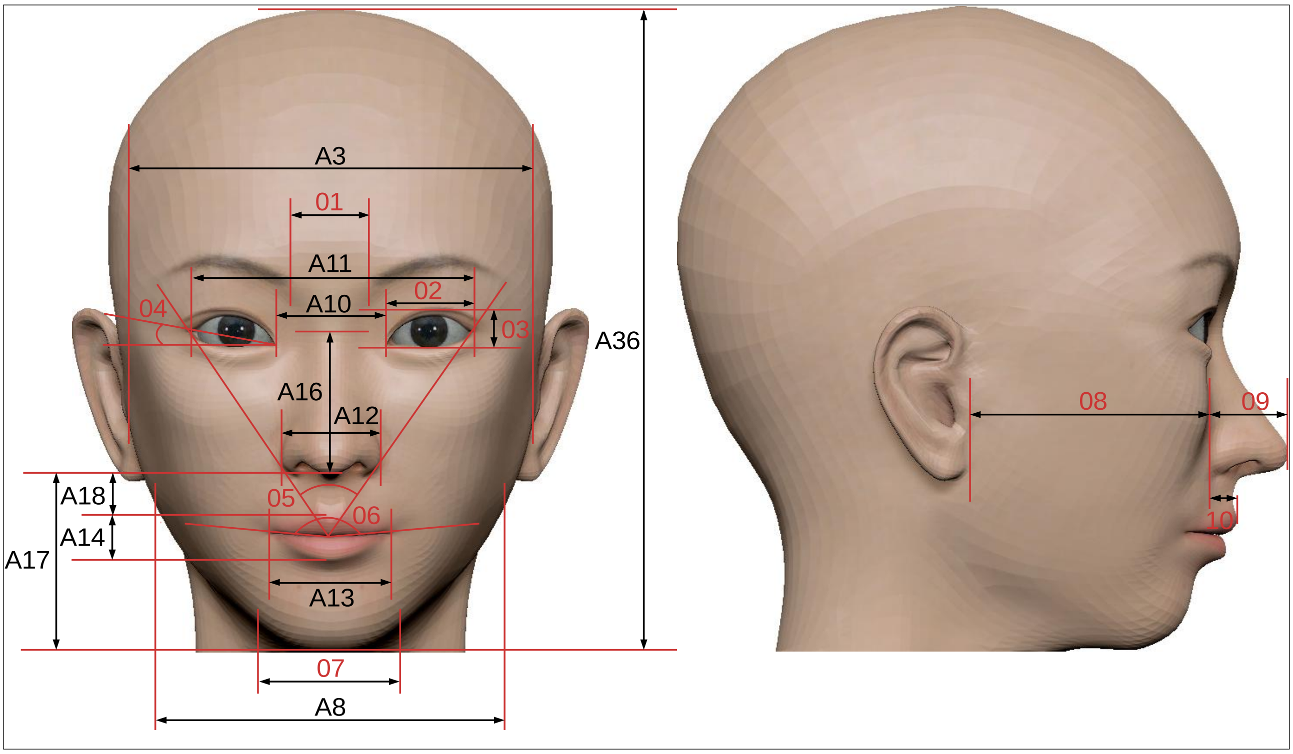

Fig.7: Measured Parts

principal component 1 were low, the subjects tended to be influenced by 02 (Eye breadth), 06 (Angle of the mouth), 08 (Profile breadth), and 09 (Nose height).

It was found that, in the group where the principal component scores for principal component 2 were high, the subjects tended to be influenced by A18 (Philtrum length), A36 (Total head height), 02 (Eye breadth), 03 (Eye height), and 08 (Profile breadth). It was found that, in the group where the principal component scores for principal component 2 were low, the subjects tended to be influenced by A8 (Bigonial breadth), A13 (Mouth breadth), A36 (Total head height), 02 (Eye breadth), 04 (Angle of the outer corner of the eye), 07 (Chin breadth), and 08 (Profile breadth).

It was found that, in the group where the principal component scores for principal component 3 were high, the subjects tended to be influenced by A8 (Bigonial breadth), A18 (Philtrum length), 04 (Angle of the outer corner of the eye), 07 (Chin breadth), and 09 (Nose height). It was found that, in the group where the principal component scores for principal component 3 were low, the subjects tended to be influenced by A12 (Nose breadth), A13 (Mouth breadth), A14 (Lip height), A36 (Total head height), 01 (Glabella), 02 (Eye breadth), 03 (Eye height), 04 (Angle of the outer corner of the eye), 07 (Chin breadth), and 08 (Profile breadth).

4. Production of variable face model

The first, second and third main components of the facial impression factors were extracted by impression evaluation. In this paper, we created a face variation system based on the increase and decrease of the three impression factors that are extracted by determining basic modeling and considered methods by which various face impression could appear. This does not simply create facial expression disorderly but face expression can be changed by operating physical values from the impression factors. With evaluation of questionnaire, numerical variation of each facial part was discussed by a face variation system based on each factor.

Fig.8: Basic Model

Figure 8 shows basic modeling to produce a variable impression face. For a production method of basic modeling, first, referring to the point that the points such as long and thin corner of the eyes, nose that is not so high, slightly blobby wings of the nose and mouth that comes out slightly over the chin, which are facial features of Orientals [3], the entire facial image was determined subjectively (note that size was not taken from photos). At that time, referring to books about beauty that list characteristics according to facial types [4] [5], a face without no features was created. As for other 24 sample images, faces which gave a different impression were created subjectively referring to stimulus words used in image research. These faces were used as sample CG images for experiments. As a result of evaluation by SD method based on this facial impression evaluation, the following three factors were obtained.

A3 (Bitragion breadth) - 12.363cm, A36 (Total head height) -20.078cm, A8 (Bigonial breadth) - 10.31cm, A10 (Interocular breadth) - 3.442 cm, A12 (Nose breadth) - 3.235 cm, A13 (Mouth breadth) - 3.82 cm, A14 (Lip height) - 1.423 cm, A16 (Nose height) - 4.619 cm, A17 (Subnasal to gnathion) - 5.505 cm, A18 (Philtrum length) - 1.192 cm, 01 (Glabella) - 2.559 cm, 02 (Eye breadth) - 2.813 cm, 03 (Eye height) - 1.152 cm, 04 (Angle of the outer corner of the eye) - 6.35°, 05 (Angle of the outer corners of both eyes from the lips) - 68.975°, 06 (Angle of the mouth) - 174.39°, 07 (Chin breadth) - 4.976 cm, 08 (Profile breadth) - 6.955 cm, 09 (Nose height) - 2.116 cm, and 10 (Mouth protrusion) - 0.819 cm

4.1. Creating a Model for Each Group

To create the Variable impression formation manufacture device, we created a model by combining the visual features with the features from the measured values for each image.

From the basic modeling, a system which was able to change to a 3DCG model with parametric information of features according to the main components was produced.

It was then possible to change the parameters for each part of the three-dimensional basic model to parameters to display each image.

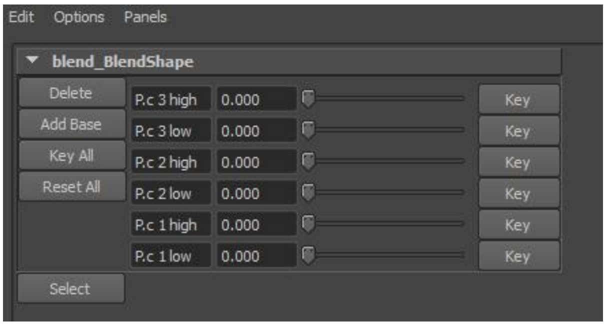

Fig.9: Variable impression formation device Menu

As shown in Fig.9, the values for the basic model template were set to '0.000' and the image modified by a third decimal place each time up to '1.000.' When extracting basic modeling by factor information of each main component, an unnatural face was obtained in the case of exceeding 1.000 and therefore the upper limit was determined 1.000

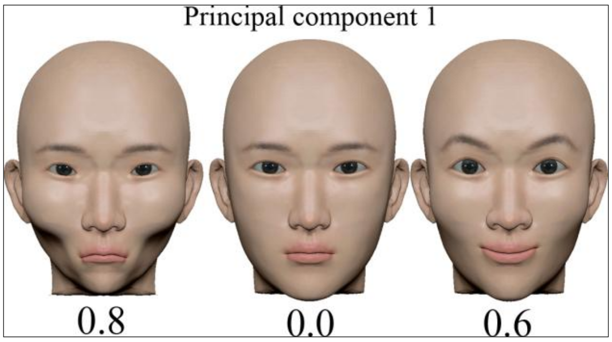

Fig.10: Verification Model for Principal Component 1

The image in the center is the basic model with the value at '0.0' and the image on the right shows the model transformed by inputting '0.6' into the characteristics of variable impression formation device that 'Favorability' scores of the principal component 1 were high.

Factors of a model having high scores of the principal component 1 relate to width of the face(A3), form of the cheekbone(08), flesh(A3・A8), form of the chin(07・A8), angle of the eyebrow, size of eyes(02・03), length of the nose(A16), size of the wings of the nose(A12), size of the mouth(A13・A14), corners of the mouth(06).

The image on the left shows the model transformed by inputting '0.8' into the characteristics of variable impression formation device that the scores for principal component 1, ' Favorability' were low.

Factors of a model having low scores of the principal component 1 relate to form of the face(07・A3・A8・A36), form of the cheekbone(08), flesh(A3・A8), form of eyes(02・03・04), thickness of lips(A13・A14), corners of the mouth(06), The width of the face(08), height of the nose(09).

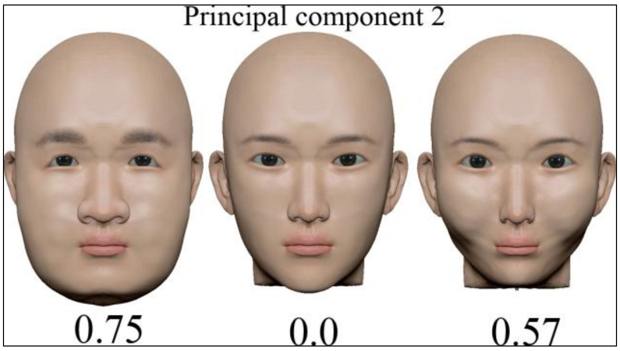

Fig.11: Verification Model for Principal Component 2

The image in the center is the basic model with the value at '0.0' and the image on the right shows the model transformed by inputting '0.57' into the characteristics of variable impression formation device that 'weight perception' scores of the principal component 2 were high.

Factors of a model having high scores of the principal component 2 relate to form of the face(07・A3・A8・A36), form of the cheekbone(08), flesh(A3・A8), form of eyes(02・03・04), length of the lower part of the nose(A18), The width of the face(08).

The image on the left shows the model transformed by inputting '0.75' into the characteristics of variable impression formation device that the scores for principal component 2, 'Weight perception,' were low.

Factors of a model having low scores of the principal component 2 relate to form of the face(07・A3・A8・A36) ,size of face(A3・A36), flesh(A3・A8), thickness of the eyebrow, form of eyes(02・03・04), size of the wings of the nose(A12), size of the mouth (A13・A14).

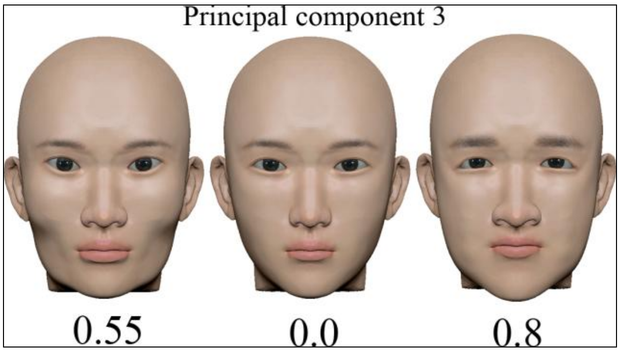

Fig.12: Verification Model for Principal Component 3

The image in the center is the basic model with the value at '0.0' and the image on the right shows the model transformed by inputting '0.8' into the characteristics of variable impression formation device that 'Power' scores of the principal component 3 were high.

Factors of a model having high scores of the principal component 3 relate to form of the face(07・A3・A8・A36), form of the cheekbone(08), flesh(A3・A8), thickness of the eyebrow, angle of the eyebrow, form of eyes(02・03・04), length of the nose(A16), height of the nose(09), size of the wings of the nose(A12), length of the lower part of the nose(A18), length of the lower part of the mouth(A17-(A18+A14))

The image on the left shows the model transformed by inputting '0.55' into the characteristics of variable impression formation device that the scores for principal component 3, 'Power' were low.

Factors of a model having low scores of the principal component 3 relate to form of the face(07・A3・A8・A36), form of the cheekbone(08), flesh(A3・A8), angle of the eyebrow, size of eyes(02・03), form of eyes(02・03・04), size of the wings of the nose(A12), size of the mouth (A13・A14),

5. Conclusion and Future Development

In this paper, the authors evaluated impression of a 3D face model using SD method and created a face transformation device based on the result. We extracted a model with the features of each main component using a face deformation device operating physical values, whose basic model originates in impression factors.

By inputting numerical values from '0.000' to '1.000,' it was possible to extract a facial model for each image. Furthermore, we found that the higher the numerical value, the stronger the resulting image. However, we also found that if we input numerical values above a certain level, some models no longer resembled a human face.

However, when entering values above certain values, an unnatural face is obtained in some models and cases and therefore the upper limit of the value was determined 1. However, when entering values more than 1 such as 2 or 3, a realistic face is not obtained through various results are obtained.

Because the 3DCG facial model used in this experiment had no outstanding features and classification was difficult, we were not able to clarify user judgment and model feature extraction. In the future, it will be necessary to conduct the experiment using a model with pronounced features, starting with the contours of the face and including the shape and angles of the eyes, nose, and lips. The authors are going to perform further impression evaluation in the future based on the face generated by this system and improve the precision.

References

[1] Tsuneyuki ABE, Megumi OHKAWA, Ruriko TAKANO, *Effect of overgeneralization on evaluation of facial impressions*, Japanese Academy of Facial Studies,Vol. 8, No. 1, 2008

[2] Miyamoto Shin-ya, Imai Jun-ichi, Kaneko Masahide, *Description of Facial Features by Words and Its Application to Retrieval of Similar Faces*, ITE Technical Report, Vol34, No.10, pp.113-116, 2010

[3] Turuoka TAKAO, *Super Dessin3*, Graphic Ltd., p30, 2002

[4] Yokoyama KEIKO, *All About Make Up Method*, Mynavi Ltd., pp12-20, 2011

[5] Kamata MAKOTO, *Facial Analysis*,Kodansha Ltd. pp65-66, 2008