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3D Definition for Human Smiles

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***Abstract*—**The study explored varied types of human smiles and extracted most of the key factors affecting the smiles. These key factors then were converted into a set of control points which could serve to satisfy the needs for creation of facial expression for 3D animators and be further applied to the face simulation for robots in the future. First, hundreds of human smile pictures were collected and analyzed to identify the key factors for face expression. Then, the factors were converted into a set of control points and sizing parameters calculated proportionally. Finally, two different faces were constructed for validating the parameters via the process of simulating smiles of the same type as the original one.

***Keywords*—**3D animation, facial expression, numerical, robot, smile parameter.

I. Introduction

A. Backgrounds

THOSE modern robots, such as machine consultants, robot officers, and virtual anchors, or those future official and housing robots, have to face and interact with people. Since more and more cold machines have been surrounding us, we will be more and more tired with those no-face monitor-only machines. So, servant robots having virtual facial expression will be a very important task for future A.I.

Nowadays, we meet the bottle neck of making virtual 3D face. For animators, they could only make lively 3D virtual character through their experiences—that means there is no way to make any 3D virtual character without try. Some times all these tries could just fail in capturing audience minds. Taking movie "Final Fantasy" as example, it cost 100 million US Dollars, and it was designed with motion capturing system to simulate the facial muscles' vibrations. However, this animation has not been as lucrative as it had been expected. Its failure and its high cost have made other film makers feel burned.

Take the box-office takings into consideration, most 3D animations take monsters, animals or aliens as main characters, and just get rid of virtual character and expressions. We still need to put a lot of efforts into virtual facial expression producing technology.

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B. Purposes of the research

The purposes of this study are to explore a numerical expression of human smiles and to create an identical facial expression in two different human faces. The results can apply to the 3D animation produce and A.I. robots' facial communications.

II. Literature Review

Ekman [1] pointed out that there are six facial expressions show emotions: happy, angry, scare, sad, and surprise, as Fig. 1 shows.[2] And some people believe that there are eight to ten kind facial expressions would show (Izard, 1971 [3][4], Plutchik, 1980[5]). The number could not be the problem. Darwin's theory, generally accepted, indicated that these basic emotions symbolizing important behavior of adapting function. For example, anger has been connected with the inclination of destroy and is presented by lowering eyebrows, opening eyes, opening mouth and showing teeth (Plutchik, 1970[6]; Izard, 1977[7]).

Fig. 1 Six facial expressions from Ekman

There are fewer numerical definitions of human facial expressions for creating virtual facial expressions in literatures. Most purposes of the related researches are developed for recognizing facial expressions, and are aimed at the need of machines' recognition. Therefore, there are a lot of control key points defined on faces in these literatures.

Irene Kotsia and Ioannis Pitas (2007) proposed two methods to recognize facial expressions: Support Vector Machine (SVM) system and Facial Action Units (FAUs) system, which are recognized by coordinates of grids and nodes[8]. Fig. 2 shows Six most representative FAUs used for facial expression recognition, including anger, disgust, fear, happiness, sadness, and surprise. Fig. 3 shows the result after simplifying the nodes.

Jaewon Sung and Daijin Kim [9] used 2D and 3D to construct facial expressions as Fig. 4 a . They defined nodes in 2D part, and then used various lines in 3D. Afterward, They used Active Appearance Model (AAM) to show facial expressions like Fig. 4 b .

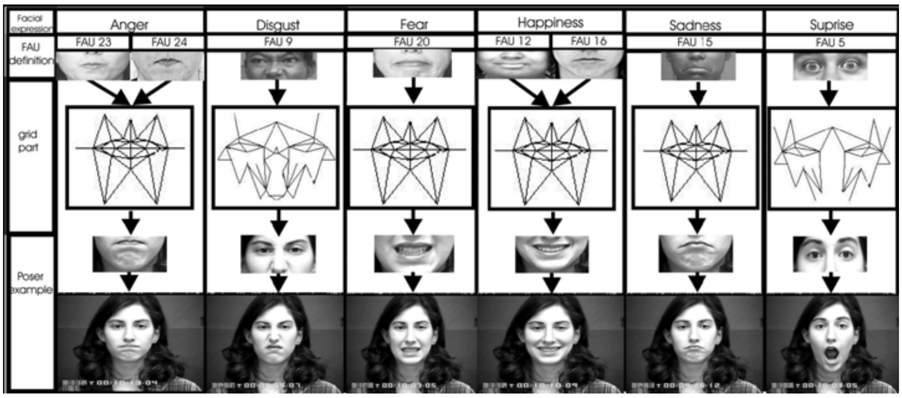

Fig. 2 Six most representative FAUs used for facial expression recognition

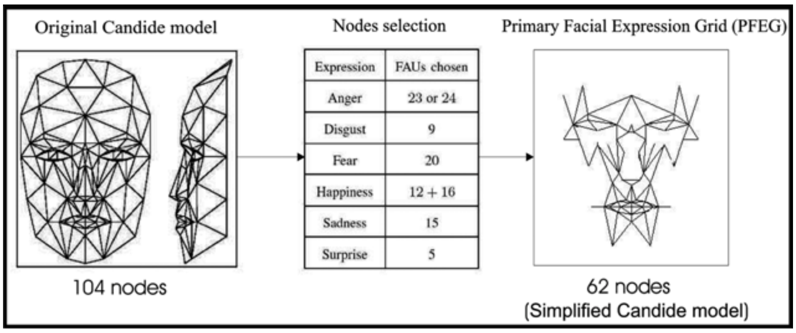

Fig. 3 PFEG according to FACS, used for the experiments.

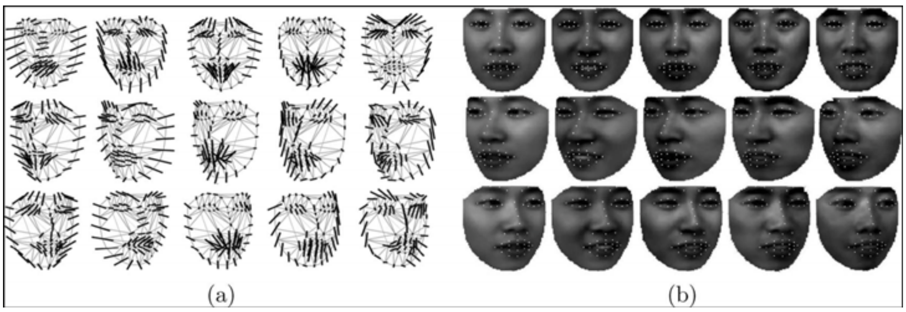

Fig. 4 2D shape and appearance variation for view-based 2D + 3D AAM—frontal model (top), right model (middle), and left model (bottom). (a)The linear shape variation modes. (b) The linear appearance variation modes.

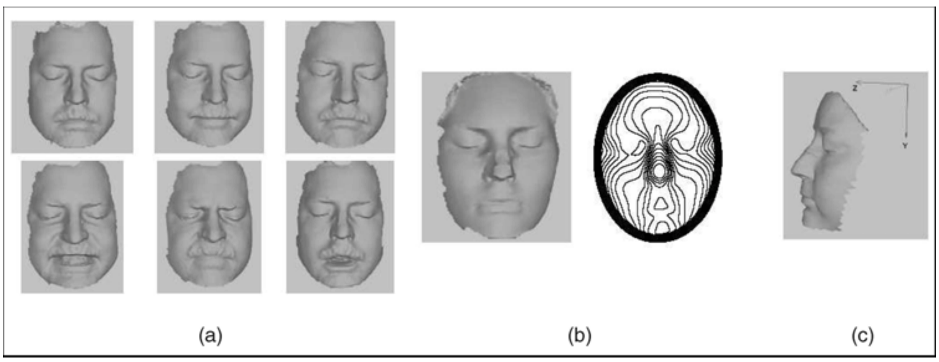

Fig. 5 (a) Examples of facial surfaces of a person under different facial expressions.
(b) Facial curves C_ for a surface S. (c) A coordinate system attached to the face.

In the paper "Three-Dimensional Face Recognition Using Shapes of Facial Curves" (2006) Chafik Samir, Anuj Srivastava, and Mohamed Daoudi [11] proposed a method to recognize facial expressions. First, they used horizontal curves called "face curves" to define facial expressions. Second, they compared the relationship between facial expressions and "face curves", shown in Fig. 5 and Fig. 6.

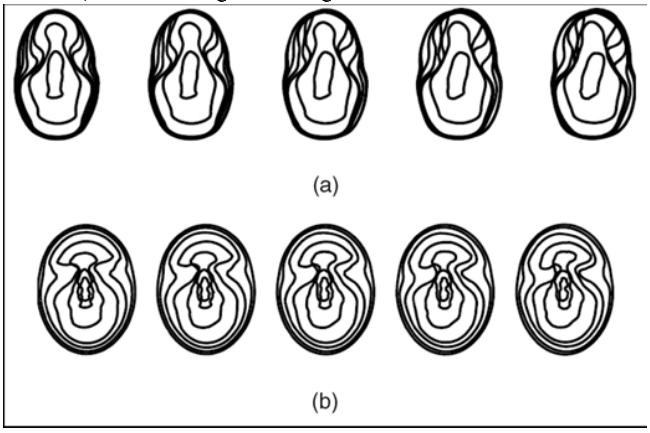

Fig. 6 Geodesic paths between corresponding facial curves. (a) Same subject, different facial expressions. (b) Different subjects.

III. Methodology

A. Collect Smile pictures

For collecting smile pictures, we invited professional drama actors and actresses in this experiment. Five males and five females, who had just graduated from departments of drama in colleges, were asked to perform as varied smiles as possible. When they performed, we took photos and got totally 116 smile pictures.

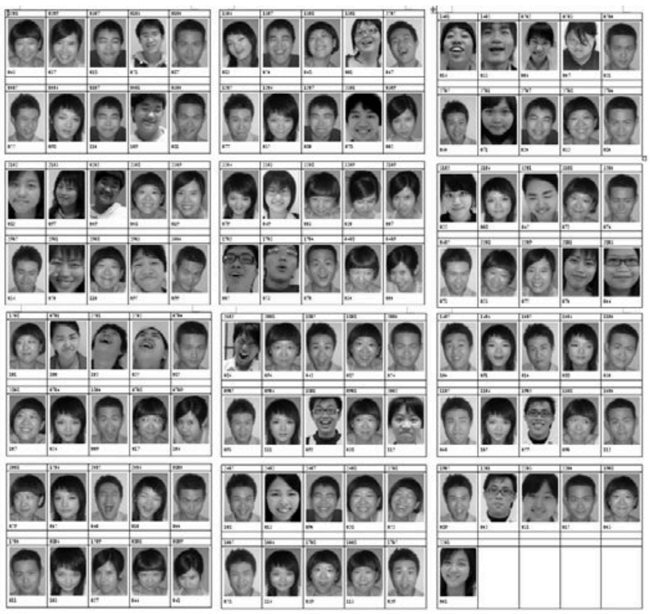

Fig. 7 Collected smile pictures

B. Set key points of facial expression

We analyzed the photo samples by observation. No matter what sexes, face shapes, skin colors, hair styles of the performers are, all key factors compose of following same items:

- Movement of Eyebrows
- Movement of upper and lower eyelids
- Movement of pupils
- Upper and lower lips
- Angle of head rotation

According to those items, the key control points of facial expressions are shown as Fig. 8.

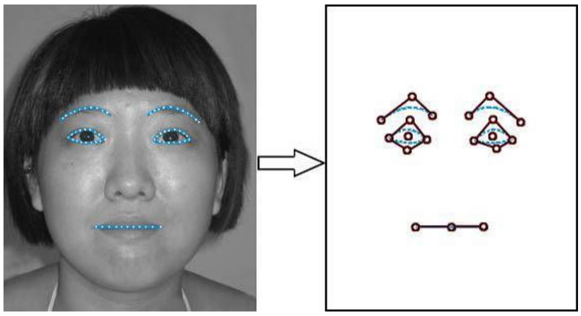

Fig. 8 A face without smile

The key control points with a changing facial expression of same character are shown as Fig. 9.

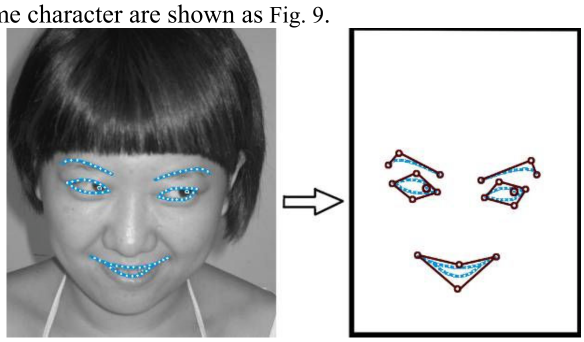

Fig. 9 A face without smile

The difference of change between those two situations was the key to convert smile into numerical data and parameters. The principle of calculating parameter must be ratios in variations of same character. In other words, one compares with oneself. Therefore, it doesn't matter which performer's face we took for this experiment. Both monster Shrek and beautiful princess were supposed to be applied the parameters well.

To compare the variation, an unchangeable datum point in common on faces was necessary. We found the two inner corners of eyes didn't move in every facial expression. The midpoint of these two corners was close to the center of every face and was suitable to be a datum point for all key control points. For that reason, we defined this point as origin for numerical smile of this study and labeled it O point. And other key control points were also labeled as TABLE and Fig. 10.

TABLE 1
CODES FOR KEY POINTS OF SMILE

Position of key points	Labels
Midpoint of two eyes' inner corners	O
Left eyebrow	LA, LB, LC
Right eyebrow	RA, RB, RC
Left eyelids	LD, LE, LF, LG
Right eyelids	RD, RE, RF,RG
Left pupil	LH
Right pupil	RH
Lips	LI, RI, J, K

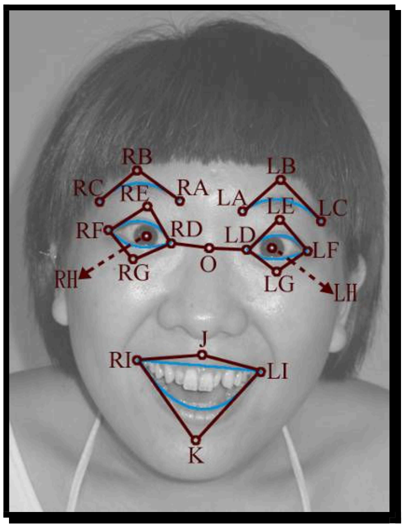

Fig. 10 Positions of key points

C. *Choose photos of a plain face and a smiling face*

We chose two photos of a male performer without glasses and with clear profiles on the face. One photo was without smile, and the other one was with smile. These two photos were handled with an image process program to crop into 400-pixel-square photos including each whole face from front head to chin, shown as Fig. 11.

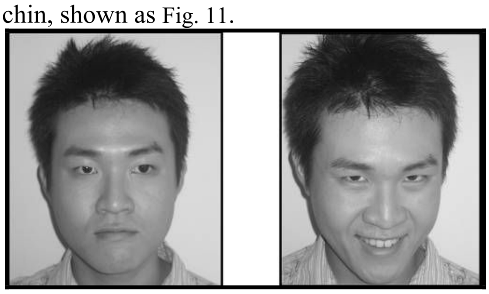
Fig. 11 Choose photos before and after smile

D. *Produce 3D samples*

From the plain-face image, we produced a 3D head model with high similarity by assistance of 3D modeling programs, Face Gen Modeller 3.1 and Autodesk Maya 2008. We also made midpoint of two eyes' inner corners of the 3D model in the position (0, 0, 0) in the 3D space, shown in Fig. 12.

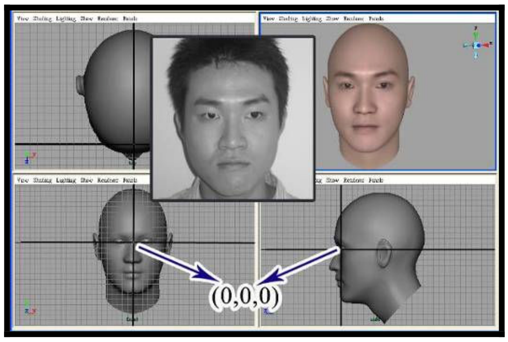

Fig. 12 3D head with a plain face

From the smiling-face image, we fixed the plain-face 3D head model by adjusting change of eyebrows, eyes, lips and the angle of head rotation to high similarity with the photo and got a 3D head with a smiling face, shown as Fig. 13.

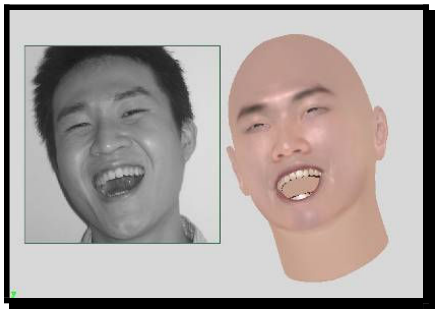
Fig. 13 3D head with a smiling face

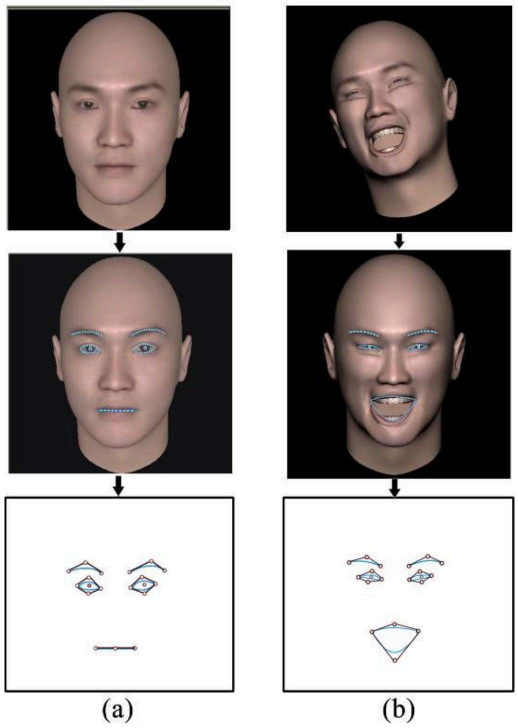

Fig. 14 Get coordinate data of key points from 3D models (a) The plain-face 3D head. (b) The smiling-face 3D head.

E. Get 3D coordinates of key points

In the 3D programs, Maya, we drew NURBS curves with key control points on the plain-face 3D head, and get coordinate (X0, Y0, Z0) of each key control point shown as Fig. 14(a).

In Maya, we got the angle of head rotation (Rx, Ry, Rz) from smiling-face 3D head, and then returned the head rotation to zero in 3 axes. Of course, the midpoint of two eyes' inner corners of the 3D model was still in the position (0, 0, 0) in the 3D space, because we didn't move the model. It was only rotated when we fixed it from a plain face to a smiling face. Now, we could get coordinate (X1, Y1, Z1) of each key control point from the NURBS curves on the straight 3D head.

F. Generate smile parameters

The coordinates of key points on face without smile were decided by the appearance of each person. In same smiles, each key control point on different faces moved with same-ratio distance and same direction. For example, the distance between an eye's inner corner and Label O of monster Shrek might be longer than that of princess Fiona, but the moving distance of her eye corner was supposed to expand in same ratio with the one of his when a same smile was made. Therefore, we assumed the ratios how much key points transfer could be applied on different faces to generate same smiles. We divided the difference between a plain face and a smiling face by the value of the plain face of the coordinate of each key point to get a changing ratio, which was called smile parameter, shown in the TABLE .

TABLE II
CALCULATION OF SMILE PARAMETER

Label	Coordinate or angle of plain face	Coordinate or angle of smiling face	Smile parameter
Rotate	0, 0, 0	Rx, Ry, Rz	Rx, Ry, Rz
O	0, 0, 0	0, 0, 0	
LA	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LB	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LC	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
RA	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
RB	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
RC	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LD	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LE	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LF	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
LG	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0
RD	X0, Y0, Z0	Xi, Yi, Zi	(Xi-X0)/X0, (Yi-Y0)/Y0, (Zi-Z0)/Z0

The results we got from the 3D models in this experiment are shown as TABLE .

TABLE III
THE COORDINATE DATA IN 3D SPACE


	Plain face			Smiling face		
	X0	Y0	Z0	X1	Y1	Z1
Rotate	0.00	0.00	0.00	-20.42	-10.82	15.21
LA	6.87	7.22	6.30	6.54	8.37	5.58
LB	15.61	11.99	6.86	15.17	12.21	7.37
LC	23.34	8.14	-2.91	23.51	7.65	-2.94
RA	-6.87	7.22	6.30	-6.54	8.37	5.58
RB	-15.61	11.99	6.86	-15.17	12.21	7.37
RC	-23.34	8.14	-2.91	-23.51	7.65	-2.94
LD	8.09	-0.04	-0.62	7.88	-0.05	-0.78
LE	14.55	5.24	3.77	13.10	3.98	4.63
LF	18.62	1.51	-2.32	18.54	1.36	-1.56
LG	14.55	-2.93	1.91	13.10	1.01	4.63
RD	-8.40	-0.20	-0.60	-8.27	-0.03	-0.77
RE	-13.66	4.93	4.43	-12.51	3.21	5.04
RF	-18.37	1.05	-1.99	-18.54	1.36	-1.56
RG	-13.66	-3.33	1.87	-12.51	0.82	5.04
LH	13.79	1.79	1.35	13.70	1.98	1.74
RH	13.68	1.52	1.54	13.79	1.83	1.74
LI	19.28	-30.17	-5.24	11.43	-27.38	-5.69
RI	-19.28	-30.17	-5.24	-11.63	-27.80	-5.19
J	0.00	-29.34	4.09	-0.01	-24.59	9.81
K	0.00	-29.53	3.66	-0.01	-50.46	1.93

The smile parameters of the type in this experiment are shown as TABLE .

TABLE IV
SMILE PARAMETERS OF THIS EXPERIMENT

Label	X axis	Y axis	Z axis
Rotate	-20.417	-10.819	15.209
LA	-0.05	0.16	-0.11
LB	-0.03	0.02	0.08
LC	0.01	-0.06	0.01
RA	-0.05	0.16	-0.11
RB	-0.03	0.02	0.08
RC	0.01	-0.06	0.01
LD	-0.03	5.64	0.25
LE	-0.10	-0.24	0.23
LF	0.00	0.00	-0.18
LG	-0.10	-1.34	1.42
RD	-0.02	-0.83	0.28
RE	-0.08	-0.35	0.14
RF	0.01	0.29	-0.22
RG	-0.08	-1.25	1.70
LH	-0.01	0.11	0.29
RH	0.01	0.20	0.13
LI	0.19	-0.09	4.07
RI	0.21	-0.08	4.58
J	-5.15	-0.15	0.10
K	-5.15	0.75	-0.78

G. Create same smiles with the parameter

After getting the smile parameters, we made all key points change from a female 3D head model and created a same facial expression with the male 3D head model in this experiment.

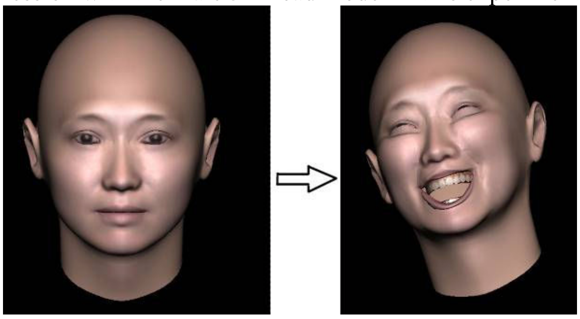

Fig. 15 Smile of a female head model

In order to check whether the smile parameters could apply on faces of a different race, we took an African face to experiment and created an identical smile, as Fig. 16.

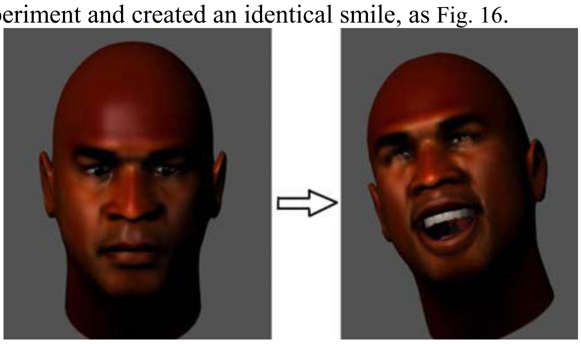

Fig. 16 Smile of an African head model

We roughly investigated the opinions about the results in this experiment. All interviewees agreed these three smiles of pictures belong to same type of smile. We believed that the smile parameter worked.

IV. Conclusion

According to the results of the experiment, we chose a specific smile to calculate the parameters and successfully created a same facial expression in other different face models. However, only the calculation method of numerical smiles doesn't match the need in practice. In the future, we will further integrate the parameters of this study with a friendly user interface to generate virtual facial expressions that 3D animators and robots need.

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