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2D to 3D Space Transformation for Facial Animation Based on Marker Data

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***Abstract*—Computer facial animation aims to create an animated character expression as natural as possible as well as human facial expressions. Using the data marker catches facial motion capture, will be determined the location of the feature points of 3D face models to follow the motion of the marker points of human faces. To overcome the morphological differences between the face of the source with the character's face, then applied with radial basis retargeting process mapping so that the character's face can still display the natural expression. Using the data marker 2D, Radial Basis Function (RBF) transformation was applied to determine the position of the feature points on the 3D face models. RBF space transformation has good ability in determining the appropriate facial motion marker points on a human face to the character's face. Motion that occurs in 3D face models is scaled according to the relative scale between the source and the target.**

Keywords—facial animation; radial basis function; marker data

I. Introduction

Human beings are very easy to recognize the non-neutrality of other human excretion especially the animated character. Changes in motion on the face for displaying an expression or movement of the chin and lips when talking points to consider in creating realistic animation. Facial expressions have played a key role in the field of nonverbal communication [1]. To approach this naturality, the facial motion capture applied to the human face. Then 3D face models represent the human face movements.

Motion capture is aimed at capturing the position and orientation of an object in physical space then record that information to be used and developed in the virtual world [2] [3]. The two greatest challenges for the use of motion capture data is lie in the application of this discrete surface sampling discontinues to drive a fine mesh, and its retargeting to face meshes of different shape and scale [4].

General approaches for facial expression synthesis can be classified into the following three categories: interpolation, muscle-based expression, and performance-driven animation and retargeting [1].

The process of retargeting is the process of transformation of space-based markers, retargeting can be defined as the process of mapping marker dots on the face to 3D face animation source models (target face). Retargeting seeks to create expressions on the characters according to the source animation expression by correlating the marker points on the source animation to 3D face models [5]. There are three techniques for performing mapping:

1. Linear mapping

The simplest approach to the retargeting process. The motion of marker position on the source animation will be followed in a linear manner by 3D face models. Linear mapping vulnerable if 3D face models have different size and shape (morphology) with a source face.

2. Scatter data interpolation

This is a non-linear approach that is capable of handling a wide range of problems in the process of retargeting. This interpolation process can estimate the location of a new points on a 3D face model of if there is a change in the face of the source by taking into account the weight of the marker points source between feature points on the face with 3D face models. The most common techniques applied in this mapping process is Radial Basis Function (RBF) interpolation, also known as radial basis mapping.

3. Art direction

Unlike the above two techniques, art direction needs a trigger from animator to determine the points of change in the 3D face models. Correlation between the source animation with animation targets defined by the animator.

With the condition of the human face and 3D face models which have different sizes and shapes, RBF space transformation has a good ability in determining the appropriate facial motion marker points on a human face to the character's face. Motion that occurs in 3D face models is scaled According to the relative scale between the source and the target [4] [6]. Marker points of the source face define the source space while the feature points of the targets face defining the space targets [7] [8].

Radial base mapping has an advantage in the speed for determining the points of retargeting, especially if the radial base mapping is done on the data marker or motion capture. The marker base (feature points) concept is used to relieve

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computing, rather than doing a computing on the surface that should calculate the whole points to building 3D face models.

This research uses a 2D facial image as input and doing the retargeting process on 3D face models using space transformation. The process of retargeting using RBF interpolation method. By using space transformation from 2D to 3D, is expected to use a single camera in facial motion capture at source face while delivering the natural expression and emotion in the 3D face models.

II. State of the Art

A. *Facial Animation*

Facial animation concentrate on the creation of realistic 3D face models by showing the right emotion [9]. There are two techniques performed in facial animation, which is based marker and markerless. Marker-based means of facial animation is done by automation approach such as retargeting feature points. Automation should be able to minimize human intervention in the process [10]. While the markerless can mean automation facial animation by using the surface as a comparison, they can be interpreted facial animation is done manually by the animator. Reference [11] explained that manual editing is always necessary: 1) the movement is expected from the 3D model is not necessarily the same/similar to the movement of people, 2) 3D face model has a proportion of/morphology that is different from the human face, 3) the placement of markers in motion capture is not always fixed and precisely at a points from day to day. Therefore, generating good facial animation is one of the most important factors in the creation of appealing, believable, and attractive characters [6].

B. *Feature Points*

The motion capture data consists of motions for the sparse feature points. Feature points aim to simplify the process of facial animation. The challenges in feature points are creating an expression as natural as possible with the number of points less than the surface blending techniques [12]. On the other hand, the use of marker means lightens computing compared to a surface algorithm that should calculate the whole points of the face. If it is deemed necessary to reuse the facial animation with a different model [13].

C. *RBF Methods*

In the 1970s, RBF methods were developed to overcome the structure requirements of existing numerical methods. RBF methods have become a well-established tool for reconstructing functions and for solving partial differential equations based on data prescribed at scattered locations [14].Four common RBFs that are globally supported and infinitely differentiable are Gaussian (1), Inverse Quadratic (2) Inverse Multiquadric (3) Multiquadric (4). The Multi Quadric is arguably the most popular RBF that used in application [15].

$$\phi(r,\varepsilon) = e^{-\varepsilon^2 r^2} \quad (1)$$

$$\phi(r,\varepsilon) = 1/(1+\varepsilon^2 r^2) \quad (2)$$

$$\phi(r,\varepsilon) = 1/\sqrt{1+\varepsilon^2 r^2} \quad (3)$$

$$\phi(r,\varepsilon) = \sqrt{1+\varepsilon^2 r^2} \quad (4)$$

III. Experimental Design

This paper proposes a program of facial animation based on the marker data using RBF space transformation, from the 2D image as source face to 3D character model as target face.

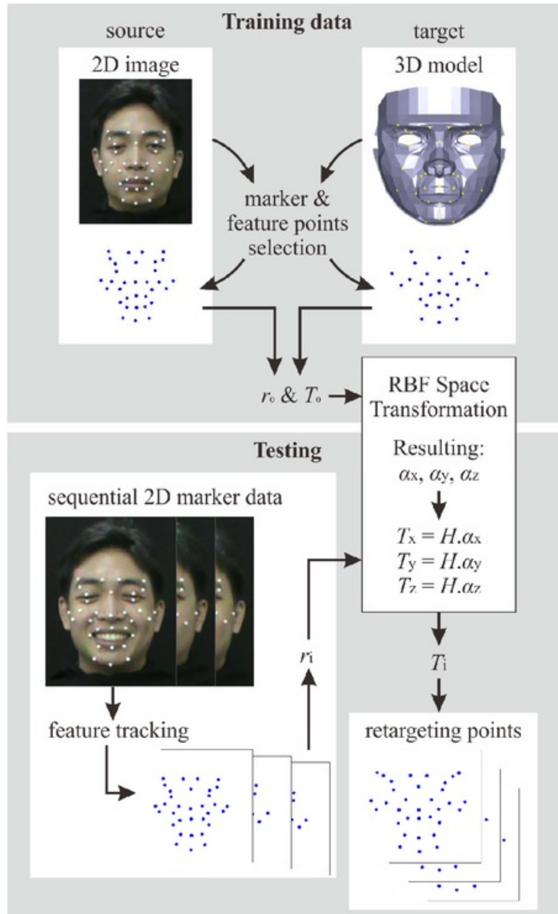


Fig 1. Schematic overview of RBF space transformation

The RBF approach constructs an interpolant as a linear combination of basis function [4].

The RBF equation is:

$$F(x) = \sum_{i=1}^{n} \alpha_i \cdot \phi(\|x - x_i\|) \quad (5)$$

The value of function ϕ depends on only upon the distance from its center and thus is called radial (6). This radial is the distance between marker points on the face of a 2D facial image.

$$\phi(\|xy_i - xy_j\|) = \sqrt{(\|xy_i - xy_j\|)^2 + r^2} \quad (6)$$

Equation (6) is an RBF multi-quadric. Value *xy* is a marker position in 2D coordinates, so use the Pythagoras theorem to calculate the distance between the marker points. Value *r* determined based on the shortest distance from all marker points on the source face (7).

$$r = min_{i \neq j}(\|xy_i - xy_j\|) \quad (7)$$

Value of $\phi(\|xy_i - xy_j\|)$ is used to build the matrix H. Then the weight value (α) for each coordinate x, y, z on the face of 3D face model obtained by:

$$T_x = H.\alpha_x, T_y = H.\alpha_y, T_z = H.\alpha_z \quad (8)$$

Let $T_x = (t_1^x, t_2^x, t_3^x, \ldots, t_n^x)$, $T_y = (t_1^y, t_2^y, t_3^y, \ldots, t_n^y)$ and $T_z = (t_1^z, t_2^z, t_3^z, \ldots, t_n^z)$, so by applying the Gaussian elimination with back substitution, from (4) is obtained:

$$\alpha_x = H^{-1}.T_x, \alpha_y = H^{-1}.T_y, \alpha_z = H^{-1}.T_z \quad (9)$$

Once the matrix H (6) and the weight of each coordinate x, y, z (9) are obtained, the retargeting feature points can be calculated quickly for each marker position from the motion of source face using (10).

$$F(x) = \sum_{i=1}^{n} \alpha_i^x . \phi(\|xy - xy_i\|),$$
$$F(y) = \sum_{i=1}^{n} \alpha_i^y . \phi(\|xy - xy_i\|),$$
$$F(z) = \sum_{i=1}^{n} \alpha_i^z . \phi(\|xy - xy_i\|) \quad (10)$$

In the testing process, sequential 2D image is extracted to locate the marker points in the source face. After obtained the value of the radial distance from the training data, the RBF space transformation will determine the retargeting points (T) in the 3D character models to calculate the weight (α) and the matrix H (ϕ).The estimation results of the feature points still consider the z coordinates of the 3D face models. So 3D face models still have depth and maintain its 3D shape.

IV. Evaluation Result

The testing of RBF space transformation for facial animation based on the markers data from 2D source to 3D face models will be presented as following.

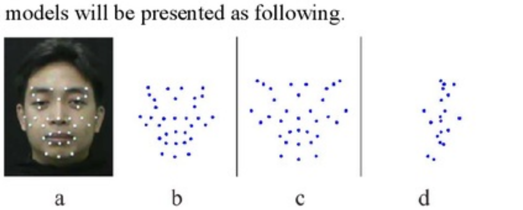


Fig 2. Neutral expression (a) 2D image from motion capture with markers information as inputs (b) marker points from source face (c) feature points from a 3D face models viewed from the front of the target face (d) feature points from the target face that has a depth (z value) viewed from the side.

Fig 2. showing a pair of training data that consists of a source face (2D facial image), in which the image has a marker information in coordinates (x, y) and the feature points of the 3D face model in the coordinates (x, y, z). At the training data, the source face and the target face shows a blank or flat expression.

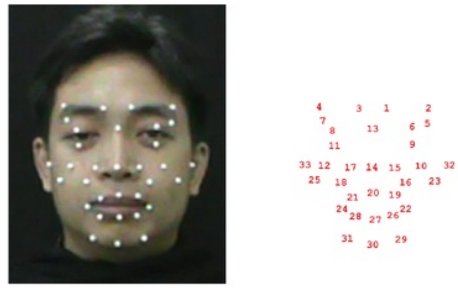


Fig 3. Thirty-three marker points on 2D facial image.

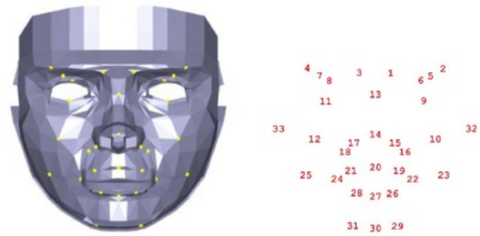


Fig 4. Thirty-three feature points on 3D face model.

There are 33 markers used to mark the feature points in the 2D facial image (Fig 3). This number is adjusted on the camera setup facial motion capture of OptiTrack [16]. The 33 markers in source face will correlate with the 33 feature points on the 3D face models (Fig 4). Motion area was able to be adaptively generated based on 3D face models, it shows the amount of percentage area formed based on feature points [17].

After performing the weighting of the training data, then testing against of 3D face models. Testing is done by the inserting image of faces that have different expressions with a training data image. Marker tracking applied to the image source to determine the coordinates of the new marker. Then RBF space transformation will estimate the 3D coordinates of the feature points for 3D face model.

A. Result

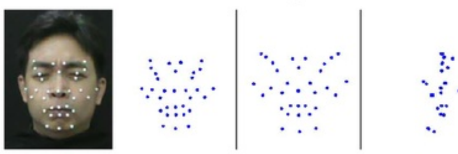
Results obtained are presented in Table 1 which contains the value of the coordinates (x, y) of the marker points of source face and coordinates (x, y, z) of the feature points of 3D face model for training data, and the result of retargeting of angry expression (Fig 5). Coordinates on the training data (source face's marker and 3D face model's feature points) are known, while the retargeting coordinates are calculated results of RBF space transformation.

TABLE I. Feature Points Result Using RBF Space Transformation for Angry Expression

Points	Training Data		Testing	
	Source (x,y)	*Target* (x,y,z)	*Source* (x,y)	*Retargeting* (x,y,z)
1	510,431	-1.30,20.27,11.64	3506,448	-1.19,19.92,11.47
2	688,429	-7.14,20.85,9.39	679,435	-6.90,20.76,9.49
3	398,436	1.30,20.27,11.64	410,455	1.00,19.86,11.49
4	233,424	7.14,20.85,9.39	253,432	6.46,20.74,9.73
5	683,496	-6.08,20.29,9.93	667,503	-5.73,20.10,9.93

6	620,513	-4.83,19.51,9.75	613,533	-4.50,18.97,9.64
7	244,485	6.08,20.29,9.93	259,494	5.61,20.20,10.01
8	285,529	4.83,19.51,9.75	298,540	4.43,19.17,9.71
9	618,585	-4.21,17.52,9.46	601,574	-3.83,17.80,9.56
10	650,681	-5.13,14.62,9.32	645,674	-4.98,14.83,9.40
11	296,592	4.21,17.52,9.46	316,583	3.69,17.82,9.64
12	256,676	5.13,14.62,9.32	268,672	4.73,14.81,9.53
13	459,517	0.00,18.40,10.67	462,521	-0.07,18.31,10.64
14	454,681	0.00,14.38,12.60	453,683	0.02,14.34,12.59
15	550,681	-2.08,15.63,10.11	549,679	-2.06,15.67,10.14
16	592,744	-3.07,13.89,9.39	585,740	-2.87,14.02,9.47
17	363,685	2.08,15.63,10.11	371,683	1.88,15.62,10.31
18	326,741	3.07,13.89,9.39	335,740	2.81,13.98,9.47
19	541,802	-1.49,11.98,9.42	526,809	-1.17,11.77,9.63
20	461,795	0.00,12.28,10.68	462,818	0.01,11.76,10.41
21	384,814	1.49,11.98,9.42	392,822	1.35,11.79,9.51
22	587,854	-3.22,11.25,8.77	581,848	-3.01,11.33,8.86
23	711,737	-6.59,13.63,7.65	706,736	-6.47,13.61,7.78
24	328,849	3.22,11.25,8.77	339,848	2.92,11.26,8.90
25	216,737	6.59,13.63,7.65	230,733	6.13,13.58,8.08
26	536,886	-2.17,10.15,9.28	531,879	-1.97,10.31,9.40
27	464,893	0.00,9.85,9.85	467,882	-0.08,10.15,9.95
28	382,891	2.17,10.15,9.28	394,884	1.83,10.32,9.49
29	569,982	-3.03,7.79,7.15	570,977	-3.07,7.88,7.20
30	454,1003	0.00,7.21,8.16	462,996	-0.22,7.29,8.26
31	349,979	3.03,7.79,7.15	360,975	2.78,7.77,7.37
32	769,672	-8.19,15.66,6.48	777,665	-8.33,15.96,6.42
33	167,669	8.19,15.66,6.48	182,665	7.76,15.52,6.93

The coordinate table above shows that the RBF space transformation able to handle repositioning the feature points of the 3D face models even though the source of motion derived from a marker on the 2D image.



a b c d

Fig 5. RBF transformation is applied to angry expression (a) 2D image from motion capture which provides information on the new marker (b) marker points from source face (c) feature points for 3D face model that obtained from RBF space transformation (d) feature points seen from the side.

B. Evaluation

Reference [18] developed the Facial Action Coding System (FACS) for describing facial expressions. The FACS is a human-observer-based system designed to describe subtle changes in facial features. FACS consists of 44 action units (AU), including those for head and eye positions. AUs are anatomically related to contraction of specific facial muscles [19].

There are six basic expressions on a human face: angry, disgust, happy, sadness, fear, and surprise [20]. Based on [21] an angry expression has AU criteria: a combination of lip tightened and lip pressor. In the feature points (Fig 5.b-d) is shown with a dots in the circle lip (19, 20, 21, 22, 24, 26, 27, 28) which docked/shrink. Disgust expression has AU criteria: wrinkled nose or upper lip raised. In the feature points (Fig 6.b-d) indicated by dots on the nose (14, 15, 16, 17, 18) wrinkles and the upper lip (19, 20, 21) which is raised. The Happy expression has AU criteria: lip corner puller. In the feature points (Fig 7.b-d) indicated by dots on the tip of the lips (22, 24) is widened and rose. Sadness expression has AU criteria: a combination of inner brow raiser + brow lowered + lip depressor or nasolabial deepener corner. In the feature points (Fig 8.b-d) indicated by dots on the brow (1, 2, 3, 4, 5, 7) is lowered and the tip of the lip (22, 24) is depressor. The fear expression has AU criteria: a combination of inner brow raiser + outer brow raiser + brow lowered. In the feature points (Fig 9.b-d) indicated by dots on the inner brow (6, 8) raise up and eyebrows (1, 2, 3, 4, 5, 7) is lower. The surprise expression has AU criteria: a combination of inner brow raiser + outer brow raiser or upper lip raised. In the feature points (Fig 10.b-d) indicated by dots on the brow (1, 2, 3, 4, 5, 7) and the inner brow (6, 8) are raised, as well as the upper lip (19, 20, 21, 22, 24).

Five following pictures (Fig 6-Fig 10) are the other result of the calculation of the RBF space transformation on six basic expressions, which (a) 2D image from motion capture with marker information as input (b) marker points from source face (c) feature points from a 3D face models viewed from the front of the target face (d) feature points from the target face that has a depth (*z* value) viewed from the side.

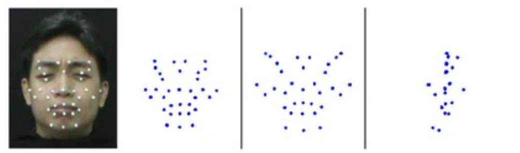


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Fig 6. RBF transformation is applied to a disgust expression.

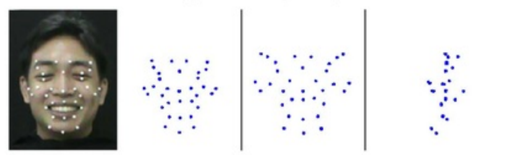

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Fig 7. RBF transformation is applied to a happy expression.

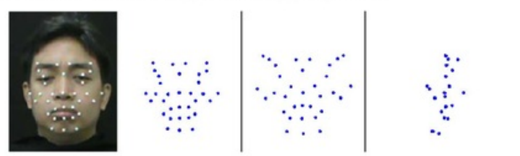

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Fig 8. RBF transformation is applied to a sadness expression.

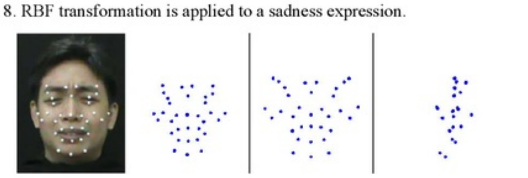

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Fig 9. RBF transformation is applied to a fear expression.

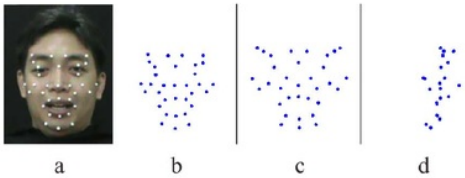

Fig 10. RBF transformation is applied to a surprise expression.

V. Conclusion

Referring to Table 1 and introduction to the RBF interpolation, RBF space transformation can relocate the feature points of 3D face model even if the source face is only captured by one camera which can only provide 2D information of marker points.

Based on the evaluation results on six basic expressions, RBF space transformation can reposition feature points on a 3D face model according to the motion of marker on 2D facial image and morphology of the target face. Space transformation experiment aims to automate the process of retargeting feature points on the facial animation.

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