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Semi Automatic Retargeting for Facial Expressions of 3D Characters with Fuzzy logicBased on BlendshapeInterpolation

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Abstract

To produce a 3D virtual character's face expression of human's natural face expressions, facial motion capture is the technique considered to be the most effective one, especially in terms of production speed. However, there are still some results showing that the expression is not so expressive, especially on the side of the 3D character which has a different facial features than the real models regarding to the application of it. In this research, the correction of the basic expressions of faces in the process of facial motion retargeting was done by using blendshape interpolation method that was based on fuzzy logic. Blendshape interpolation method is the method used to combine multiple shapes into one blend with the concept of interpolation. In this research, the process of blendshape meets the concept of linear interpolation which the movement of a point of vertexon blendshape used straight lines . Blendshape method will be run as a proofreader on the results of retargeting process. The weighting of blendshape will be assigned automatically from the results of the calculation of fuzzy logic, which refers to the input of the marker position of the facial motion retargeting. This weight is then used to provide improvements to create more expressive expressions. This process will be easier and faster to do than doing customize one by one at the vertex point manually. To avoid the appearance of irregular motion (haphazard movement), it is necessary to give the limitation of the weight (weight constraint) with range of [0,1].

Keywords : Blendshape, retargeting, fuzzy logic, facial motion capture.

1. INTRODUCTION

Computer character animation is now a much needed component in various applications such as in the world of games, movies, web pages, computer human interface, and even in the fields of communication and psychology studies. The characters are used for varied purposes, ranging from being just a usual figureto being used as a simulation of detailed character's expression.

To create a convincing character, the main thing to pay attention on is the real and realistic movement and facial expressions as the face is a source of identity and a mood sign for what is happening. While face - expressions also has a variety of elements, ranging from open - lid mouth, forehead and cheek wrinkles, and even to the enlarging and shrinking pupils.

Traditional modelling in making animated characters' faces were formed by moving facial muscles manually. Although the formation of expression facial expressions are made one by one with the details manually to produce a good quality of expression, but this method is expensive and the process takes a long time and goes very slow, while the animated film studios currently take creativity and pursue faster time to do this. By this, it is much needed to know how to do the faster and cheaper process with the support of interactive applications facilities.

For almost 35 years, the research and the formation technique of automation process of the character animation has been done, and most of the techniques derived was based on motion capture that is sometimes called the method of driving the display, that is the process of capturing the movement of a model which is then converted and expressed in the form of animation. Generally on the side of the models are placed a marker in any important points that become the source of muscle movement, but in its development, some are done with no markers/marker-less. This model nowadays had been developed and specified towards specific parts. The research of motion capture animation of facial gestures or facial expression motion capture is the part having a lot of attention. In such a research, the facial expression of characters is expected to form a high suitability in terms of expression and may represent true emotion that occurs in the model. Facial motion capture generally provides some types of facial capture using low resolution from 32 to 300 markers with the system of active and passive markers [1].

However, this research is said not to be perfect in the field as there are still some discrepancy and emotion of the expression when referring to the original model. To optimize this, the author will present this research study by doing an approach using the method of blendshape from facial motion capture data that has been done in previous studies.

2. RELATED WORKS

Firstly, facial motion capture was run in the animation of "Mike, The Talking Head", which the model is driven by a mechanical controller that is built specifically to control some point on face including the mouth, eyes, muscle contraction, and the position of the head (Figure1 (a)). Though this technology can be done in real time, but the mechanical devices are usually large and rather heavy, so it is not comfortable and not flexible to use.

The next newer technology was optical technology (Figure1 (b)). With the capture technique, it reduces nuisance of the mechanical system, this technology allows the models to move freely. This technique often uses retro-reflective markers that glows when it is brought to light, so that it makes the tracking easier to run especially for realtime applications. In the next development, there are also techniques for tracking without markers/markerless, but up to now the technique is not strong enough for realtime performance.

(a) (b)

Figure 1 . Examples of facial motion capture system ; (a) Mike , The Talking Heads , the first mechanical tools in making facial expression synthesis [4] , (b) Vicon , motion capture cameras are widely used today [1]

2.1 Scanning and Data Collection Process

Along with the development of technology scanners and cameras , there are at least three ways you can do to make a virtual 3D face models , it can be made manually by using 3D modelling software, capturing 3D models with digital pen, or doing a direct capture of the man with the camera/scanner [1] . Cristobal Curio et al. [3] did scanning 3D facial animation using ABW Scanner as in Figure2. Scanner consists of two LCDs of line projector and three CCD video cameras that can record the entire surface of the face, then completed by the digital camera of Canon EOS 10D SLR which is associated with flash Profotosystems. After the first calibration process, the scanner will calculate 3D information using coded light approach that will generate measurements for each pixel from each CCD cameras.

In the process the one-time scan, the device can generate four independent 3D data, the process is carried out to produce a thorough surface that can be connected to each other. With the calibration information , the color information of an SLR camera is projected onto the surface of the face to produce detailed textures. This procedure is used in order to perform the scan once again to the actor 's face, but capable to produce the basic expressions up to 46 times.

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

Figure 2. (a) ABW scanner and (b) an example of the facial scan , (c) motion capture system and (d) installation of reflective markers [3]

As for the process of data collection of facial motion capture, it wastaken from another actor with a six cameras of motion capture video conference (vicon) 612 that worked on 120Hz wave which was formed circular about 1.5 meters from the face. A total of 69 markers were installed to record the appearance of facial expressions, and 3 additional markers were placed on the head as the head tracking targets (Figure2 (c) and Figure2 (d)). In this process, the recording of the expression was done by the same instructions as in the first step of scanning techniques. At this stage, at least the actor can perform a series of basic expression as many as 25 models of expressions.

After the process of capturing the facial expressions, marker was then reconstructed and given a label, the error of triangulation occured was removed manually and if there is a gap/space between the marker installation, it was then necessary to do cubic spline interpolation. Finally, the peak of the frame with the maximum amplitude in facial expressions will be identified in each expression for the analysis at a later stage.

2.2 Retargetingof Facial Animation

Movement exhibited by a model was aimed to be demonstrated as exact, natural and expressive as the virtual character's movement set as targets (Figure3 is a general schematic retargeting process).

There are many variations of methods that can be used to do retargeting process of the motion capture data. With reference to the format of the raw data from the motion capture and keep attention to how much the data of facial movements is analyzed and what type of facial parameters are met. There are two categories of methods that can be done to deal with this, that are providing motion parameters explicitly, or implicitly [1] .

Figure 3 . Retargeting of facial animation [1].

Cristobal Curio (2006) conducted a natural facial motion retargeting by deforming the face as a linear combination of basic elements. 3D model of the target character is formed by scanning of the source, then the result of the frame peak was built from each basic facial expressions effectively creating a model morphing for 72 marker positions that include the same basis as that used in the 3D model . Model morphing at the motion capture markers was then used in the optimization process to predict the contribution of each of the basic elements of facial expressions, which are then combined in every frame it through [3]. Figure4 shows the schematic process of retargeting facial motion.

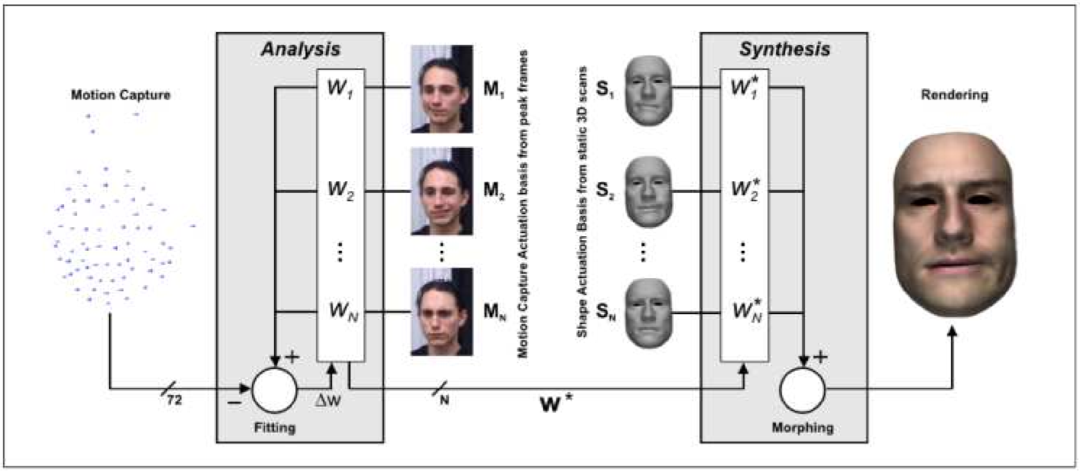


Figure4 . 3D animation system of retargeting face [3]

In Figure4, it is shown that the use of morphing M motion marker (M_1 - M_N) was semantically matched to the S shape morphing 3D models based on the results of the scan (S_1 - S_N). The data movement of the facial motion capture can be decomposed into w* morphing N and done the retargeting to a 3D model rendering results .

2.3 Basic Concepts of Linear Interpolation Based on Blendshape

Blendshape, in the field of computer graphics of blendshape, is the method used to combine multiple shapes into one blend with the concept of interpolation [7]. To illustrate in more detail how the movement of the vertex point linear interpolation with some form of 3D blendshape process, it is simply illustrated in Figure 5. Suppose that three different forms keyshape are given as in Figure 5, (a) the basic shape, (b) keyshape 1, and (c) keyshape 2.

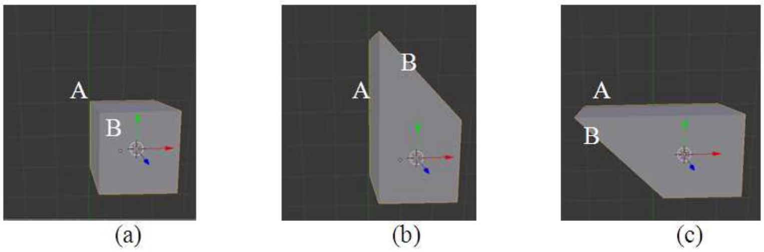


Figure 5. The examples of changes in shape with the concept of linear interpolation

Keyshape 1 is formed from the basic shapes by dragging points A and B as far as 2 plots along the axis z+. Keyshape 2 is formed from the ground state by shifting the points A and B as far as 2 plots along the axis y-. To combine keyshape 1 and 2, two successive transformations are done. First, keyshape 1 is well formed, followed by the formation of the keyshape 2 from the the keyshape 1. The detail can be seen more in Figure 6.

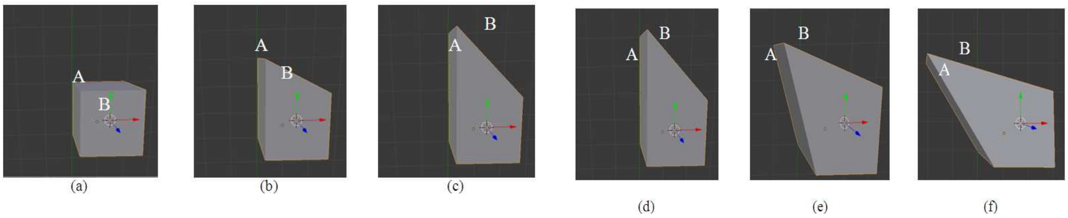


Figure 6. (a,b,and c) the process of formation of basic form keyshape 1, (d, e and f) the process of formation of keyshape 2 from keyshape 1

From the process in Figure6, it can be concluded that the merger of the two keyshapes occured sequentially and changes only occurs at certain points that are converted from the basic form. In Figure6 (a, b, and c), keyshape 1 is formed from basic shapes and amendments meet the concept of linear interpolation. In Figure6 (d, e, and f) keyshape 2 is formed from keyshape 1 and still meet the concept of linear interpolation [2], because the points A and B shifts following a linear line formed by the initial point and end point.

In the study of mathematical, interpolation method is a method to determine the points between a number of points (n) using the function of particular approach. Linear interpolation is used to determine the points between two points in a straight line .

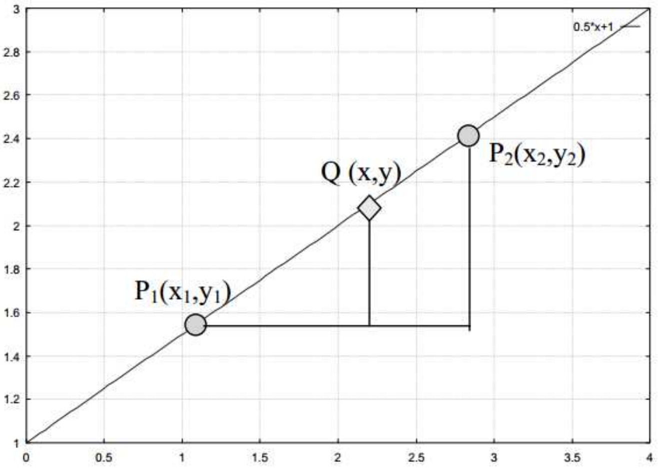


Figure 7 . Linear interpolation curve

In Figure7, with the first point of P_1 and end point P_2 , then it can be obtained points between the straight line connecting the points P_1 and P_2. The equation of a straight line through two points P_1 (x_1, y_1) and P_2 (x_2, y_2) can be written :

$$\frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1} \tag{1}$$

so that it can be obtained the equations of linear interpolation as follows :

$$y = \frac{y_2-y_1}{x_2-x_1}(x-x_1) + y_1 \tag{2}$$

So, if you look at the change in Figure6, the shift of the points A and B is obtained from the linear shift continuously from initial position to the final position, in accordance with the concept of linear interpolation.

2.4 Blendshape on 3D Character Faces

Blendshape technique for an animator is very popular because this method can be done with a simple linear interpolation motion that can interpret facial expressions of a 3D character. The general illustration in this discussion is the formation of facial expressions of the target 3D character which is formed from the weight of basic expressions models such as happy, sad, anger, fear, disgust, and surprise. All expressions are designed and prepared by weighting constraints (constraints) between the range of 0 to 1, 0 means being neutral conditions or without weights, while 1 is a condition where the weight given to the maximum value.

Animation on the target of the default models is made in the form of neutral, while the weighting expression animation is formed in the state of maximal expression. So that with the shape interpolation weighted through each of the basic expressions, it is expected to form a certain expression as planned. Suppose that if angry expression is desired, it can be given weight by the expression of the mouth open 0.5 and 0.7 for forehead wrinkles and so on.

Figure8 is the example of blendshape models created using Autodesk Maya. The model is placed at the center position, while around him is an expression of the target weighting formed under maximal condition. In Figure8, the expression is weighted by opening mouth, blink, constrict the forehead, and so on.

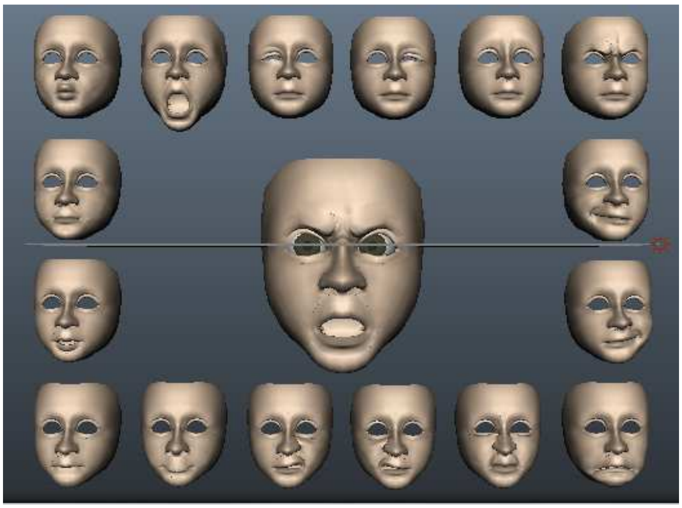
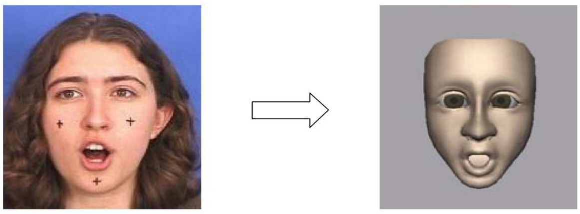


Figure 8 . Blendshape in Autodesk Maya. The centre is the target blendshape animation, while around him are forming weights in expression variation

2.5 Blendshape Retargeting

In general, in the process of blendshape retargeting, Erika S. Chuang [1] described it as follows (for more clear description, see Figure9); the input of the movement is put in the process of blendshape retargeting, that is $\boldsymbol{S} = [\,\vec{S}(1), \vec{S}(2), \ldots, \vec{S}(t)]$,each frame is a function of keyshape derived from the source model ($\mathbf{B}_{\text{source}}$) and weights corresponding to the keyshape (Ω). Thus, S(t) = F($\mathbf{B}_{\text{source}}$, Ω (t)), where $\mathbf{B}_{\text{source}} = \{\overrightarrow{B_{S1}}, \overrightarrow{B_{S2}}, \ldots, \overrightarrow{B_{Sk}}, \}$ and $\boldsymbol{\Omega} = \{\omega_1, \omega_2, .. \omega_k\}$.



$$\mathbf{S}(\mathrm{t}) = \sum_{i=1}^{k} \omega_{\mathrm{i}}(\mathrm{t}).\,\mathrm{B}_{\mathrm{si}} \qquad \Omega(\mathrm{t}) \qquad \mathbf{T}(\mathrm{t}) = \sum_{i=1}^{k} \omega_{\mathrm{i}}(\mathrm{t}).\,\mathrm{B}_{\mathrm{Ti}}$$

Figure 9. Blendshape retargeting with linear function [1]

By providing the input data of **S**, the function of F ($\mathbf{B}_{\text{source}}$, Ω(t)), and the keyshape of source $\mathbf{B}_{\text{source}}$, blendshape retargeting will serve to divide the weight Ω (t) at each frame in the data source. While on the side of the target, it takes a set of equations or keyshape analogy association that can be installed on the target model, so that the $\mathbf{B}_{target}\mathbf{B}_{target} = \{\vec{B}_{T1}, \vec{B}_{T2}, .., \vec{B}_{Tk}\}$. In this case, the process of analogy is free, depending on like what the source will be designed and specified. In the retargeting process, the weight Ω is simply taken and provided as the input on the target model, then the function $\mathbf{T}=[\vec{T}(1), \vec{T}(2), .., \vec{T}(t)]$,should be completed, where $\vec{T}(t)$= H ($\mathbf{B}_{target}$, Ω(t)). The function of F($\mathbf{B}_{target}$, Ω (t)) and H($\mathbf{B}_{target}$, Ω (t)) is not always the same as each has dependencies on its own keyshape parameters. So, a keyshape is described as a series of control nodes (vertice) in a form of a 3D volume. In general, a linear weighting function for source models can be solved by the equation (3).

$$\vec{S}(t) = \sum_{i=1}^{k} \omega_i(t).\vec{B}_{Si} \quad (3)$$

The same linear function is also used in the target model as equation 4 illustrated:

$$\vec{T}(t) = \sum_{i=1}^{k} \omega_i(t).\vec{B}_{Ti} \quad (4)$$

Weights $\omega_i(t)$ has the same value for the source and the target, and can be positive or negative.

For more details , the following illustration of the blendshape retargeting on the side of the target is given to match the equation 4 in Figure10.

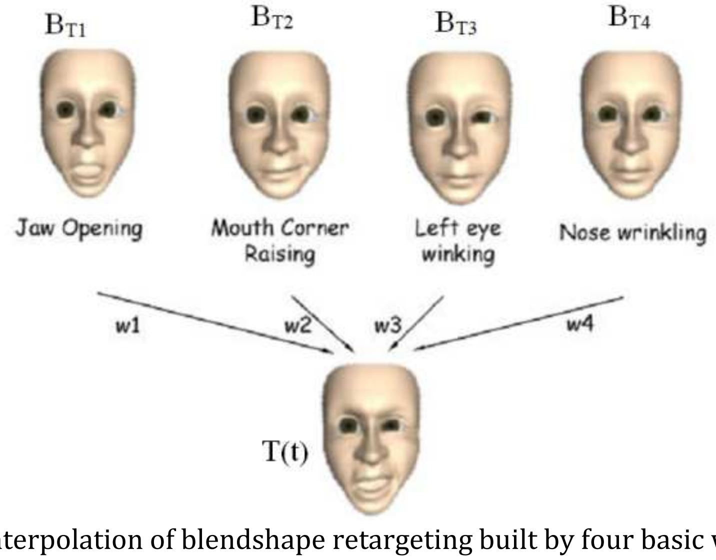


Figure 10. Interpolation of blendshape retargeting built by four basic weighting (ω) [1]

Figure10 matches the equation of blendshape retargeting which is as follows:

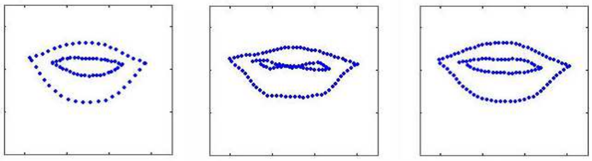
$$\vec{T}(t) = \omega_1(t).\vec{B}_{T1} + \omega_2(t).\vec{B}_{T2} + \omega_3(t).\vec{B}_{T3} + \omega_4(t).\vec{B}_{T4} \quad (5)$$

which is T $\vec{}$ (t) is a new expression of a combination of four basic expressions, those are with their respective weights .

Furthermore, the set of keyshape for data sources is given representing the position of a point on the contour of the lips, as in Figure11 (a). Furthermore, the rearrangements contours is done and then used as keyshape to the target model. From the shape of the lips given, equation 3 cannot guarantee the validity of retargetingwhen it is applied to the keyshape of the target as shown in Figure11 (b). In its testing, the picture is an example of lip motion animation that makes the output is distorted, this is caused by the input weights which receive the positive and negative point so that the weight is negating or neutralizing each other [1]. To minimize the potential for error due to the weight of the input, the input weights should be limited only to the weight that has a positive point ($\omega i \geq 0$). So that the equation 4 becomes the equation 6.

$$\vec{S}(t) = \sum_{i=1}^{k} \omega_i(t).\vec{B}_{si,}, \qquad \omega_i \geq 0 \quad (6)$$

These restrictions will make the weight relatively small so keyshapes inputs used is not too complicated to do. With this restriction, the positive and more realistic form is successfully achieved (Figure11 (c)).



(a) (b) (c)

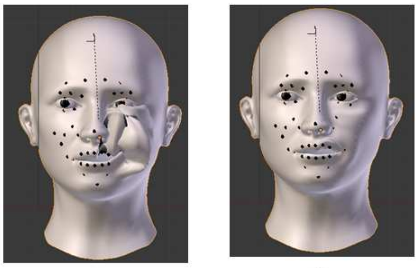
Figure 11. The weight of the animated blendshape retargeting; (a) The basic form of the lips, (b) the results of the distorted shape of the lips , and (c) the results of lip shape with a positive value [1]

2.6 Haphazard Movement Restrictions

In a moving a 3D model of facial expression, an animator is actually doing the movement by moving the interpolation *vertex* from one point to another, and the process can be done to any direction on the x , y or z. Although Blendshape method is presented with the movement of the active vertex set point from the neutral point to the specified model's expression point with a particular design, but in principle it also has the same problem, that is the animator can assign weights (ω) which is minus or too large, such as the concepts that have been discussed in the previous sub. Thus, in order to avoid haphazard movement or irregular movements that are not well controlled, the control weights (ω) should be given the limitation or constraint.

In equation 6, the constraint has been given, thatis the weights should be positive ($\omega \geq 0$), however, these limits still cannot guarantee that there is haphazard movement occured. Thus, an additional constraint is required with the range of [0, t], which t is 1.

The example in Figure12 shows an expression that can occur on the face of the character in 3D, which (a) is the circumstances for positive weights ($\omega \geq 0$) with ω=10, while (b) is the conditions of the expression that has been given weight constraint ranged ω = [0, 1].



(a) (b)

Figure 12. The haphazard movement constraint: (a) The weight with no constraints with t = 10, (b) the weight with constraint limit ω = [0,1].

2.7 Basic Facial Expression Related to Emotion

A research about basic human facial expression has been conducted for several decades. Many disputes about the amount of basic expressions which become the foundation of all existing expressions. According to Ekman, there are at least five basic expressions related to the emotions that are put in the results of the research done by psychologists who are expert in expression, i.e. happy, sad, anger, fear and disgust. Table 1 shows some opinions from psychologists about the names of the basic expressions of human emotion.

Table 1. Classification of basic emotions in the view of the expert psychologist [11]

Name	Classification of basic emotions
Plutchik	Anger, anticipation, trust, disgust, joy, fear, sadness, surprise.
Ekman, Friesen, Ellsworth	Anger, disgust, fear, joy, sadness, surprise.
Frijda	Desire, happiness, interest, surprise, wonder, sorrow.
Izard	Anger, contemp, disgust, distress, fear, guilt, interest, jpy, shame, surprise.
James	Fear, grief, love, range.
Mowrer	Pain, Pleasure.
Oatley dan Johnson-Laird	Anger, disgust, anxiety, happiness, sadness.

Plutchik [14] describes the composer of the basic emotions and their relation with other emotions in the form of the wheel emotion as illustrated in Figure13.

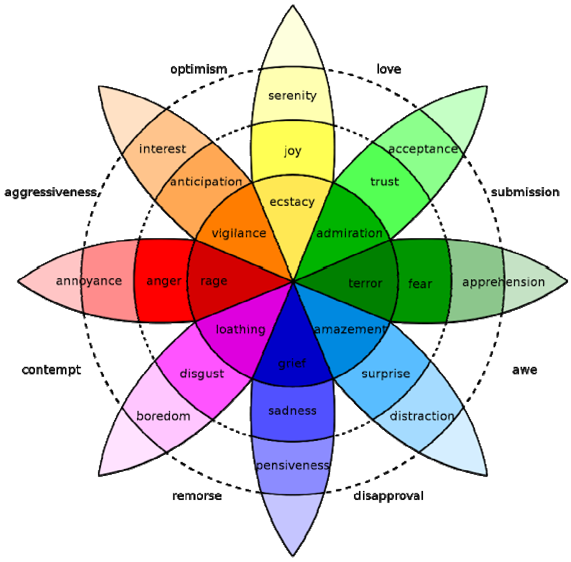


Figure 13 . Plutchik's concept of emotional relations [14]

The cone shape as in Figure13 describes the intensity, the further it is out, the longer intensity takes place. While the shape of the circle represents the emotional closeness from one to another.

To form a 3D virtual facial expressions naturally , it is necessary to note the characteristics of the expression stated by the experts above. In the database creation of JIFFE - 3D [10] that has been done in previous research, the concept of Ekman, Freisen, and Ellsworth is used. They say that facial expressions of human emotion is essentially divided into six basic expressions, i.e. anger, disgust, fear, happy, sad, surprised [13]. From a research conducted Ekman, et al., Murat Tekalp and Jorn Osterman [12] make a parameter known as Facial expression Animation Parameters (FAP). Of six expressions studied, they describe the expression parameters as in Table 2.

Table 2. Facial expressions of Basic Emotions [12]

Basic Emotion	Description
Joy	The eyebrows are relaxed. The mouthis open and the mouth corners pulledback toward the ears.
Sadness	The inner eyebrows are bent upward.The eyes are slightly closed. Themouth is relaxed.
Fear	The eyebrows are raised and pulledtogether. The inner eyebrows are bentupward. The eyes are tense and alert.
Anger	The inner eyebrows are pulleddownward and together. The eyes arewide open. The lips are pressedagainst each other or opened toexpose the teeth.
Disgust	The eyebrows and eyelids are relaxed.The upper lip is raised and curled,often asymmetrically.
Surprise	The eyebrows are raised. The uppereyelids are wide open, the lowerrelaxed. The jaw is opened.

From the description of the parameters in Table 2, Murat Tekalp and Jorn Osterman [12] subsequently make simple 3D visualization of a character 's face as shown in Figure14.

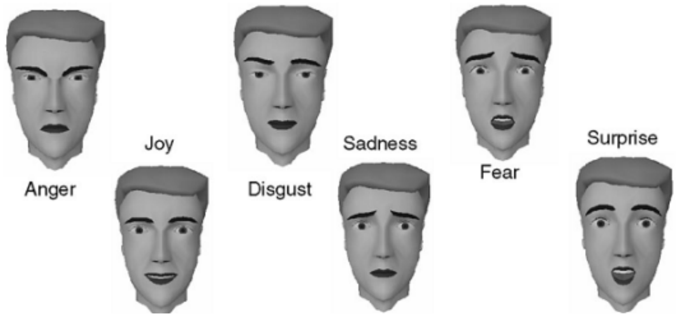


Figure 14 . Basic facial expressions related to emotions[12] .

3 . ORIGINALITY

In this system, there would be a combination between the concept of retargeting done, which is, the process that moves the animation of face currently done by animator using motion capture technology and blendshape method, that is, the incorporation of some basic expressions into a particular expression to fit the concept of the animator who designed or based on the patterns of emotion expression research that has been done by the experts.

The incorporation of these two methods will provide new patterns and some advantages, including (1) by the concept of pure retargeting, facial animation distortion can occur, especially if the source/actor and the target 3D character has different facial features, (2) it can be said that the expression resulted in the target does not yet fit the level of expressiveness as expected, so that with the blendshape method by setting up basic expressions that have been previously established and the appropriate combination of fuzzy computational results will be more precise and produce an expression that appropriate as expected or even more expressive based on the concepts of expression studies suggested by experts.

4 . SYSTEM DESIGN

Generally, the research methodology flowchartofSemi Automatic Retargeting for Facial Expressions of 3D Characters with Fuzzy logic Based on Blendshape Interpolation is shown in Figure15 below:

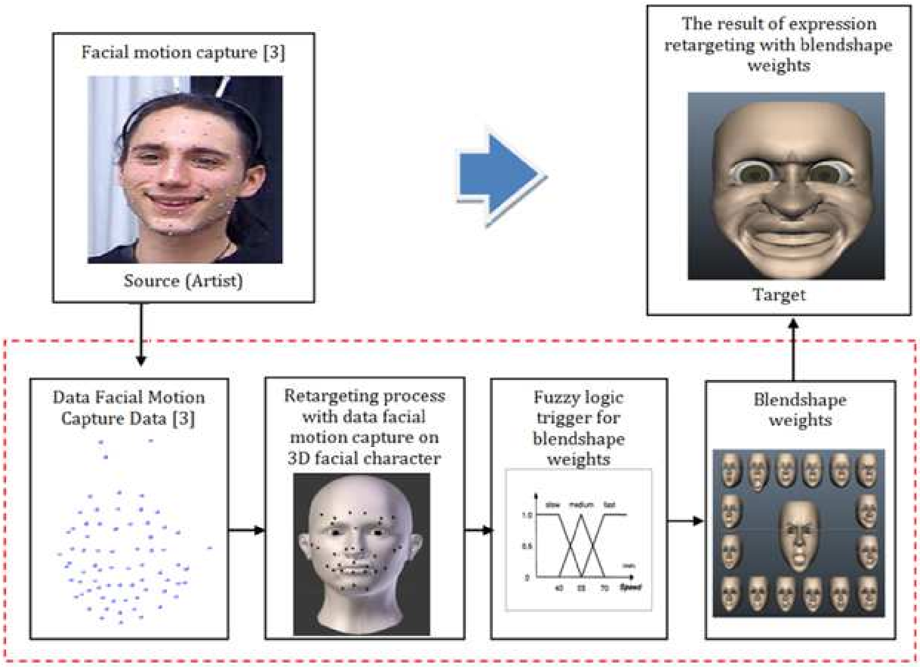


Figure 15. The flowchart diagram of research methodology for Semi Automatic Retargeting for Facial Expressions of 3D Characters with Fuzzy logic Based on Blendshape Interpolation

4.1 The Installation of Facial Motion Capture

It is said to be semi-automatic because the setting-up process of the data points of the motion capture which is recorded was done manually in the setting-up on a 3D face model, but the movements of the expressions and the process to move facial muscles from the recording scene continues to run automatically according to the movement exhibited by the models. The process carried out first is attaching data points of facial motion capture on the mesh or facial skin surface of virtual characters used as targets. Areas that will be given markers are the head, eyes, nose, mouth, and cheeks. Part of facial features which is given markers in detail is described in Table 3 and the it lays down as shown in Figure15.

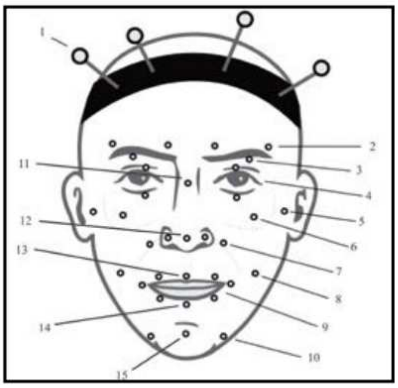


Figure16 . Laying area of the markers on facial features [10]

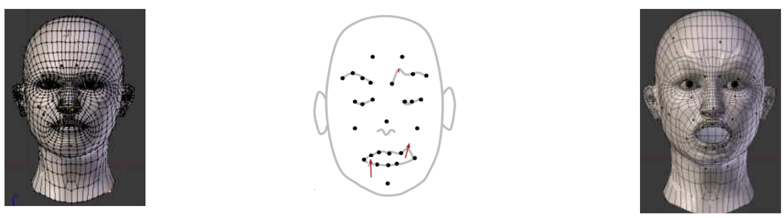
Table3. The area of the markers on facial features [11]

No.	Face Area	Amount of Markers	Notes
1.	Head	4	-
2.	Eyebrow	2	Markers were laid on the right and the left side of the face symmetrically
3.	Orbital upper	1	
4.	Eyelids	2	
5.	Ear	1	
6.	Orbital lower	1	
7.	Nostril base&bulge	2	
8.	Puffer	1	
9.	Lip and mouth	3	
10.	Jaw end	1	
11.	Nose bridge	1	-
12.	Nose tip	1	-
13.	Upper lip	1	-
14.	Lower lip	1	-
15.	Chin	1	-

4.2 Design Model Keyshape

To create a set of models that will be used as the basic expression blendshape weighting on the target, the first to be designed is keyshape. In this research, every keyshape applies a weight of [0,1] which 0 means the value of neutral and 1 is the maximum expression of given conditions.

In every designing one keyshape, the vertex points of the existing neutral expression condition must be replaced or designed to maximal expression conditions. Figure17 shows the process of how to design a neutral emotional expression of the condition into an expression of surprise to make the shift of the point vertex .



(a) (b) (c)

Figure 17. Examples of the process of making keyshape with a surprised expression: (a) neutral expression (at first) , (b) shifting the vertex point to get a state of shock, (c) the final condition after the removal of the vertex surprised keyshape

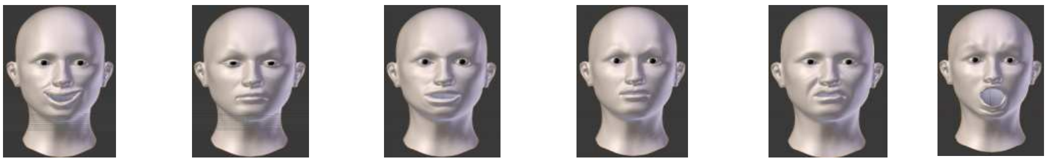
So, after the completion of the keyshape design, according to the concept of linear displacement interpolation discussed in the previous section, every point of the vertex moves straight from initial conditions (neutral) towards the end of the condition. Figure 18 is an example of the expression resulted after shifting keyshape from 0 toward 1 on the keyshape of surprise.

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

Figure 18. Examples of the process of moving shapes in keyshape with a surprised expression

Figure 18 (a) shows a neutral expression or initial. (b, c, and d) is the condition of the expression in the transition to a surprised expression, each weight is 0.3, 0.6, and 0.9. (e) is a maximum condition of the surprised expression keyshape by the weight of 1.

Referring to the research about basic expressions proposed by Ekman, Freisen, and Tomkins [13], there are six basic expressions which covers all the emotions that exist, those are angry, sad, happy, surprise, disguste and scare. Therefore, in this study those all basic expressions are formed and used as a weighting on facial blendshape. From five keyshapes made, Figure19 is the maximum condition of six basic expressions of the blendshape weighting in this research.

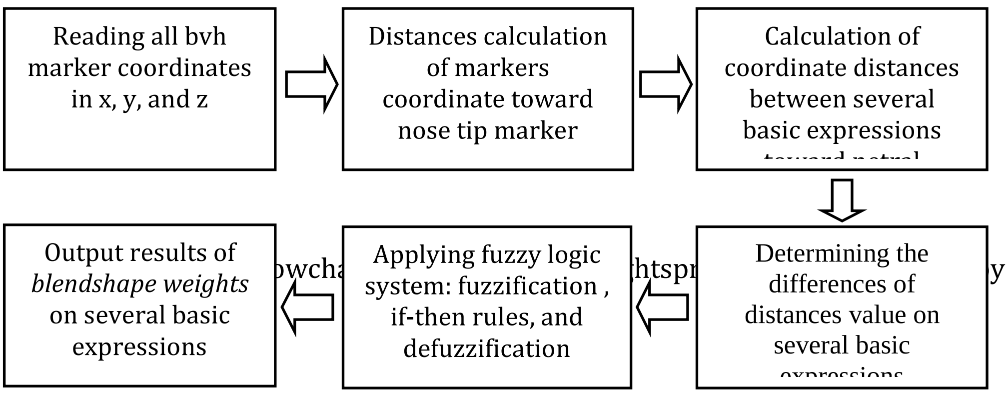


Joy Sadness Anger Fear Disgust Surprise

Figure 19. Six forms of weighting blendshape expression in Blender 2.5

4.3 Fuzzy logic as a stimulus of Weight Blendshape

In order that the blendshape weights given in each frame is created with approaching size, a system stimulus of the blendshape weights will be created based on the fuzzy logic. Figure20 shows an overview of fuzzy logic flow as the decision giver and determinant of the weight point on the blendshape.



The first process to be done in making this a fuzzy logic system is reading the difference between the coordinates of marker points on the data BVH. In order to have simplicity in identifying the difference between the distance of the point markers that will be used as an input information to the fuzzy, and because the shape of the face is symmetrical, it will be chosen only along one side of the critical points that can represent the parameter capturing the movement of facial muscles corresponding to the traits of 6 basic expressions, so that the fuzzy logic can be more effective in the process of calculation and can decide what kind of expression is produced and how many blendshape weights should be calculated to have more expressive 3D facial expressions. The markers selected are 10 markers and 1 center point read based on the coordinate of the data. Figure21 shows the marker points are read and referenced as the movement of face muscles.

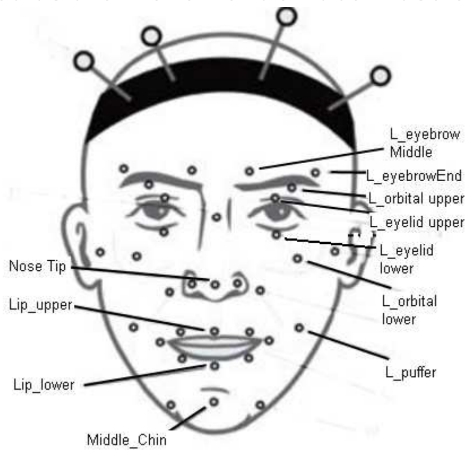
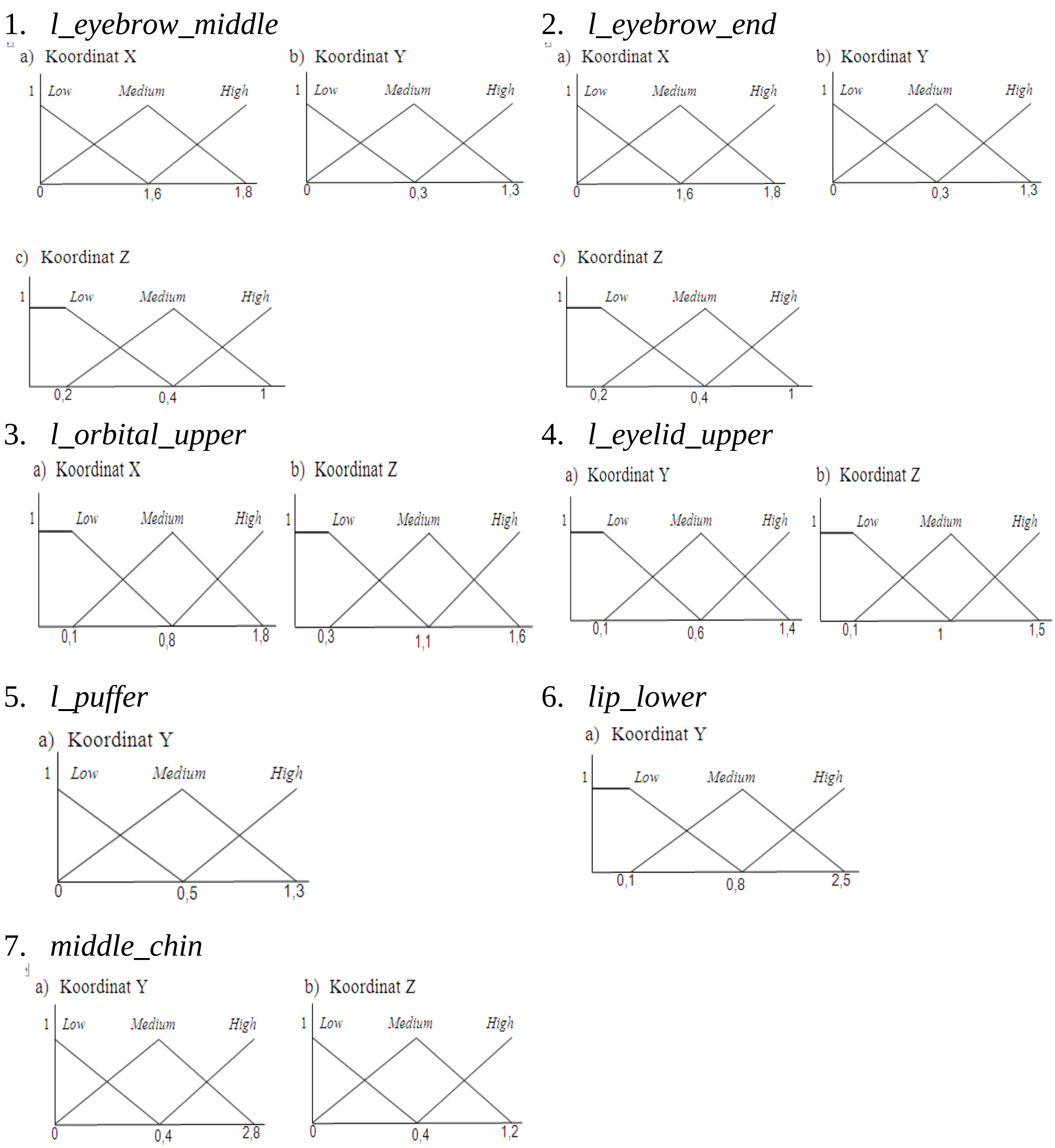


Figure 21. Markers that will be read as fuzzy logic input

From the data of the coordinate translation of x, y, and z in Figure21, all the coordinates of each marker in the expression of which is used as a model, the distance will be calculated from the center point of the Nose Tip. The coordinates of the six expressions used as a model point are recorded when the best poses according to research conducted earlier, that is a Database Arrangement of Javanese-Indonesian Female Facial Expression BAsed on 3D Marker for Emotion Recognition [10]. After the distance is calculated as well, the results will be compared to the neutral expression of each of these expressions.

4.3.1 Fuzzification

The design of membership functions is taken from the maximum value, medium, and minimum values from the difference between expression coordinates with the neutral one that has a value as a differentiator against other expressions, such as expressions of sadness, fuzzification membership functions is only done on l_eyebrow_middle, l_eyelid_upper, and l_orbital_lower at the y coordinate because based on Table 3, coordinates y and z, the markers of l_eyebrow_middle, l_eyelid_upper, and l_orbital_lower at the sad expression does not have a distinct difference in the value of the other expressions. And the same happens to the other markers. Figure 22 shows each of Membership Function (MF) or membership functions are constructed.



Gambar 22. Fuzzy Logic DesignSystem

In the design of fuzzy logic in Matlab, the above fuzzification is then designed as an input parameter, while the output is routed directly to the destination of some basic expressions, i.e. happiness, sadness, anger, fear, disgust and surprise. Then, if-then rules are made in order that the output expected can be achieved as well as or almost close to the referred data.

4.3.2 The Provision of *If-then* rules

After mapping the membership function, the next step is to give the premise of the rule (if, then) under the conditions specified by the expression coefficient with range [0,1]. In this research methodology, the rules are prescribed and divided into six basic expressions as follows:

1) Rules on JOY expression :
[R1] IF l_eyebrow_middle_X is HIGH and l_orbital_upper _X is HIGH then JOY=1
[R2] IF l_puffer_Y is HIGH then JOY =0,5
[R3] IF lip_lower_Y is HIGH and middle_chin_Y is HIGH then JOY =1

2) Rules on SADNESS expression :
[R4] IF l_eyebrow_middle_Y is HIGH and l_ eyelid_upper_X is HIGH then SADNESS=1

3) Rules on ANGER expression :
[R5] IF l_eyebrow_end_Z is LOW and l_orbital_upper _Z is LOW then ANGER=1
[R6] IF l_ eyelid_upper_Y is MIDDLE then ANGER=0,5

4) Rules on FEAR expression :
[R7] IF l_ orbital_upper_Z is HIGH and l_ eyelid_upper_Z is HIGH and middle_chin_Z is HIGH then then FEAR =1

5) Rules on expression of DISGUST :
[R8] IF l_eyebrow_middle_Z is HIGH and l_eyebrow_end_Z is HIGH and l_eyelid_upper_Z is HIGH then DISGUST = 1
[R9] IF lip_lower_Y is MEDIUM and middle_chin_Z is HIGH then DISGUST =0,7

6) Rules on SURPRISE expression :
[R10] IF l_eyebrow_end_Z is MEDIUM then SURPRISE =0,5
[R11] IF l_ orbital_upper_X is MEDIUM and l_ orbital_upper_X is MEDIUM then SURPRISE =0,5
[R12] IF l_ eyelid_upper_Z is HIGH and middle_chin_Z is MEDIUM then SURPRISE =1

4.3.3 Defuzzification

After the fuzzy rules set, the process to be followed next is defuzzification. For the Sugeno fuzzy systems, defuzzification is sought by calculating the average value. Equation 7 shows the calculation of the output value at a particular expression.

$$\text{The output of emotion} = \frac{\sum_1^n Ri * MF\_in}{\sum_1^n Ri} \quad (7)$$

Ri is the value of each expression rules, while MF_in is the value of Membership Function (MF), the results of fuzzification.

Suppose that the anger expressions, the fuzzy value on the MF is from [R5] and [R6] are respectively 0.3 and 0.2, then according to the if-then rules on the expression of anger, it is shown as follows :

[R1] IF l_eyebrow_end_Z is LOW and l_orbital_upper _Z is LOW then ANGER = 1

[R2] IF l_ eyelid_upper_Y is MIDDLE then ANGER = 0.5

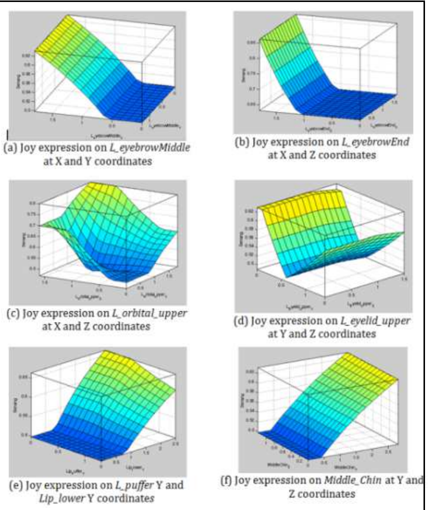
So we get anger emotion for overall output is $= \frac{0.3\ (1)+0.2(0.5)}{0.3+0.2} = 0.8$

5 . RESULTS AND ANALYSIS

For the test of the Blendshape weights resulted from the fuzzy logic process stimulated on each basic expression of retargeting process, the basic expression data which is used as the reference of expression will be firstly tested, the process of testing the fuzzy logic system will be applied to the 13 input data that have been chosen and described in the chapter of research methodology. Once after the reference data obtained and it shows the appropiate output of blendshape weights, it will be then used as a reference so that when it is tested, the examples from other data of basic expressions can provide the appropriate values and expressions randomly as parameters of reference data that has been entered in the fuzzy logic system. Here are some test results of blendshape weights with the basic expression weights resulted from the calculation of fuzzy logic system.

1. Joy Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Joy - *L_eyebrow Middle* (1.8,0.52,0.36) - *L_eyebrow End* (1.62,1.3,0.47) - *L_orbital upper* (1.79,0.65,0.3) - *L_eyelid upper* (1.13,0.07,0.2) - *L_eyelid lower* (0.77,0.21,0.24) - *L_orbital lower* (0.09,1,0.46) - *L_puffer* (0.54,1.1,0.02) - *Lip_upper* (0.33,0.27,0.03) - *Lip_lower* (0.76,2.53,0.24) - *Mid_Chin* (0.74,2.77,0.03)	- *L_eyebrow Middle* (1.8,0.52,0.36) - *L_eyebrow End* (1.62,-,0.47) - *L_orbital upper* (1.79,-,0.3) - *L_eyelid upper* (-,0.07,0.2) - *L_puffer* (-,1.1,-) - *Lip_lower* (-,2.53,-) - *Mid_Chin* (-,2.77,0.03)	Joy: 0.63 Sadness: 0 Anger: 0.21 Fear: 0 Disgust: 0 Surprise: 0.03		

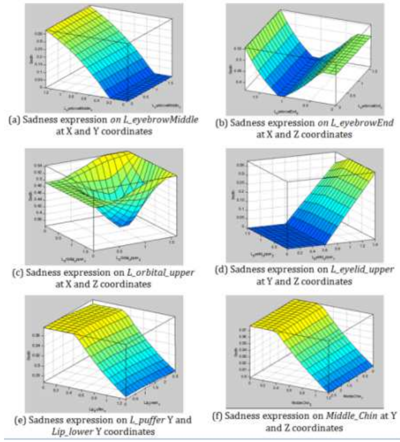


(a) Joy expression on *L_eyebrowMiddle* at X and Y coordinates
(b) Joy expression on *L_eyebrowEnd* at X and Z coordinates
(c) Joy expression on *L_orbital_upper* at X and Z coordinates
(d) Joy expression on *L_eyelid_upper* at Y and Z coordinates
(e) Joy expression on *L_puffer* Y and *Lip_lower* Y coordinates
(f) Joy expression on *Middle_Chin* at Y and Z coordinates

Figure 23. Test result of joy expression

2. Sadness Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Sadness - *L_eyebrow Middle* (0.55,1.34,0.41) - *L_eyebrow End* (0.18,0.58,0.95) - *L_orbital upper* (0.85,0.5,0.95) - *L_eyelid upper* (0.75,1.39,0.7) - *L_eyelid lower* (0.33,0.92,0.37) - *L_orbital lower* (0.29,1.15,0.9) - *L_puffer* (0.32,0.44,0.3) - *Lip_upper* (0.36,0.05,0.11)	- *L_eyebrow Middle* (0.55,1.34,0.41) - *L_eyebrow End* (0.18,-,0.95) - *L_orbital upper* (0.85,-,0.95) - *L_eyelid upper* (-,1.39,0.7) - *L_puffer* (-,0.44,-) - *Lip_lower* (-,0.58,-) - *Mid_Chin* (-,0.55,0.21)	Joy: 0 Sadness: 0.4 Anger: 0.02 Fear: 0 Disgust: 0 Surprise: 0.3		

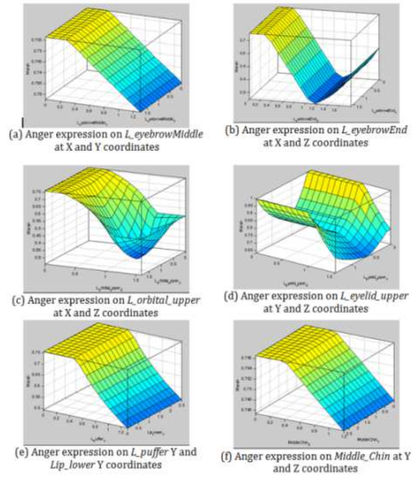


(a) Sadness expression on *L_eyebrowMiddle* at X and Y coordinates
(b) Sadness expression on *L_eyebrowEnd* at X and Z coordinates
(c) Sadness expression on *L_orbital_upper* at X and Z coordinates
(d) Sadness expression on *L_eyelid_upper* at Y and Z coordinates
(e) Sadness expression on *L_puffer* Y and *Lip_lower* Y coordinates
(f) Sadness expression on *Middle_Chin* at Y and Z coordinates

Figure 24. Test result of sadness expression

3. Anger Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Anger - *L_eyebrow Middle* (0.01,0.02,0.25) - *L_eyebrow End* (0.03,0.02,0.28) - *L_orbital upper* (0.06,0.05,0.32) - *L_eyelid upper* (0.05,0.66,0.07) - *L_eyelid lower* (0.17,0.12,0.28) - *L_orbital lower* (0.07,0.07,0.06) - *L_puffer* (0.08,0.02,0.19) - *Lip_upper* (0.22,0.19,0.2) - *Lip_lower* (0.11,0.12,0.11) - *Mid_Chin* (0,0.01,0.14)	- *L_eyebrow Middle* (0.01,0.02,0.25) - *L_eyebrow End* (0.03,-, 0.28) - *L_orbital upper* (0.06,-, 0.32) - *L_eyelid upper* (-,0.66,0.07) - *L_puffer* (-,0.02,-) - *Lip_lower* (-,0.12,-) - *Mid_Chin* (-,0.01,0.14)	Joy: 0 Sadness: 0 Anger: 0.76 Fear: 0 Disgust: 0 Surprise: 0		

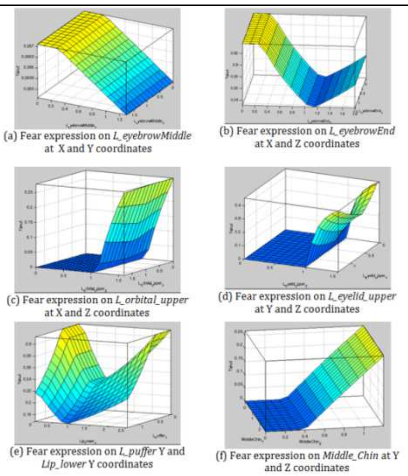


(a) Anger expression on *L_eyebrowMiddle* at X and Y coordinates
(b) Anger expression on *L_eyebrowEnd* at X and Z coordinates
(c) Anger expression on *L_orbital_upper* at X and Z coordinates
(d) Anger expression on *L_eyelid_upper* at Y and Z coordinates
(e) Anger expression on *L_puffer* Y and *Lip_lower* Y coordinates
(f) Anger expression on *Middle_Chin* at Y and Z coordinates

Figure 25. Test result of anger expression

4. Fear Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Fear - *L_eyebrow Middle* (0.65,0.24,0.82) - *L_eyebrow End* (0.97,0.58,1.75) - *L_orbital upper* (0.7,0.19,1.58) - *L_eyelid upper* (0.68,0.62,1.37) - *L_eyelid lower* (0.37,0.03,0.62) - *L_orbital lower* (0.57,1.32,0.95) - *L_puffer* (0.61,0.65,0.33) - *Lip_upper* (0.37,0.1,0.38) - *Lip_lower* (0.43,0.24,0.08) - *Mid_Chin* (0.23,0.06,1.22)	- *L_eyebrow Middle* (0.65,0.24,0.82) - *L_eyebrow End* (0.97,-,1.75) - *L_orbital upper* (0.7,-,1.58) - *L_eyelid upper* (-,0.62,1.37) - *L_puffer* (-,0.65,-) - *Lip_lower* (-,0.24,-) - *Mid_Chin* (-,0.06,1.22)	Joy: 0.03 Sadness: 0 Anger: 0.18 Fear: 0.27 Disgust: 0.23 Surprise: 0.02		



(a) Fear expression on *L_eyebrowMiddle* at X and Y coordinates
(b) Fear expression on *L_eyebrowEnd* at X and Z coordinates
(c) Fear expression on *L_orbital_upper* at X and Z coordinates
(d) Fear expression on *L_eyelid_upper* at Y and Z coordinates
(e) Fear expression on *L_puffer* Y and *Lip_lower* Y coordinates
(f) Fear expression on *Middle_Chin* at Y and Z coordinates

Figure 26. Test result of fear expression

5. Disgust Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Disgust - *L_eyebrow Middle* (0.55,0.33,0.98) - *L_eyebrow End* (0.65,0.29,1.47) - *L_orbital upper* (0.84,1.06,1.39) - *L_eyelid upper* (1.13,0.46,1.49) - *L_eyelid lower* (0.58,0.14,0.58) - *L_orbital lower* (0.19,0.82,1.94) - *L_puffer* (0.52,0.21,0.65) - *Lip_upper* (0.21,0.04,0.19) - *Lip_lower* (0.02,0.99,0.4) - *Mid_Chin* (0.41,0.25,0.97)	- *L_eyebrow Middle* (0.55,0.33,0.98) - *L_eyebrow End* (0.65,-,1.47) - *L_orbital upper* (0.84,-,1.39) - *L_eyelid upper* (-,0.46,1.49) - *L_puffer* (-,0.21,-) - *Lip_lower* (-,0.99,-) - *Mid_Chin* (-,0.25,0.97)	Joy: 0 Sadness: 0 Anger: 0.1 Fear: 0.12 Disgust: 0.28 Surprise: 0.21		

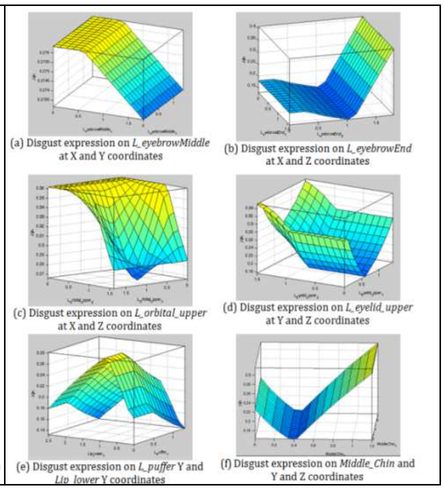


Figure 27. Test result of disgust expression

6. Surprise Expression

Coordinate distance to normal exspression (x,y,z)	13 data input for fuzzy logic (x,y,z)	Fuzzy output value for blendshape weights	Blendshape expression before weighted by fuzzy output	Expression after weighted by fuzzy output
Surprise - *L_eyebrow Middle* (0.21,0.11,0.23) - *L_eyebrow End* (1.2,0.27,1.17) - *L_orbital upper* (1,0.29,1.23) - *L_eyelid upper* (0.63,0.53,1.42) - *L_eyelid lower* (0.72,0.22,0.6) - *L_orbital lower* (0.46,0.65,0.45) - *L_puffer* (0.27,1.29,0.26) - *Lip_upper* (0.56,1.25,0.11) - *Lip_lower* (0.16,1.34,0.05) - *Mid_Chin* (0.18,1.22,0.57)	- *L_eyebrow Middle* (0.21,0.11,0.23) - *L_eyebrow End* (1.2,-,1.17) - *L_orbital upper* (1,-,1.23) - *L_eyelid upper* (-,0.53,1.42) - *L_puffer* (-,1.29,-) - *Lip_lower* (-,1.34,-) - *Mid_Chin* (-,1.22,0.57)	Joy: 0.14 Sadness: 0 Anger: 0.1 Fear: 0.01 Disgust: 0.02 Surprise: 0.33		

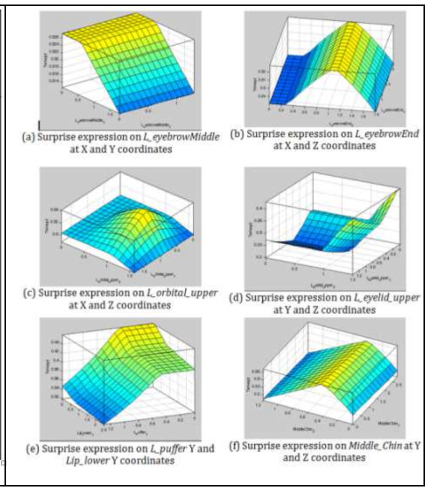


Figure 28. Test result of surprise expression

From some testing of the expression that has been done, there are still a number of the output mixed with other points of expressions that are not addressed, though greatest overall output is correct and refers to the figure as expected. This is reasonable since there are some expressions that have similar characteristics between one each other. As well as the expression of disgust and surprise, in the testing, both have the same results when they are matched to a database of expression, the same position of the markerenables them to have the same point of lip and cheek wrinkles.

The testing is done only refers to one type of reference expression database that has been set, this condition will run stable when the tested expression refers to the database . However, in practice, there are some variations in the kinds of expressions, such as anger with and one without the open mouth, or other expressions. Therefore, further research in the development of a reference database should be further enriched with several variations on each of the existing expression.

6 . CONCLUSION

From the research that has been done, some conclusions obtained in the process of retargeting, blendshape interpolation, and at last the result of fuzzy logic. The process of retargeting facial motion capturedata to 3D face character does not always produce an expressive face, therefore the role of the level of blendshape method to the character's expressiveness is very significant.

In the six basic expressions database that is used as the reference of fuzzy logic, the expression of JOY is the easiest one to do in identifying the data because a lot of difference in the distribution of data has a significant value and different from others. While the expression of ANGRER is difficult enough to be identified because the difference value between one in the data and one in neutral expression is very small. This condition may cause the data that will be tested in blurred condition or skewed towards the value of other expressions.

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