# Linear Deformation on 3D Face Model for Facial Animation

Joannes Agung Satriyo Pamungkas
Master of Informatics Engineering
University of Atma Jaya Yogyakarta
Sleman, Indonesia
155302361@students.uajy.ac.id

Suyoto
Master of Informatics Engineering
University of Atma Jaya Yogyakarta
Sleman, Indonesia
suyoto@mail.uajy.ac.id

Samuel Gandang Gunanto
Department of Animation
Indonesian Institute of The Arts
Yogyakarta, Indonesia
gandang@isi.ac.id

***Abstract*— Facial animation an important part in the 3D virtual world which is the process of moving the character's face in 3D according to the joint motion that follows the reference human face. Importance of expression in the world of animation is a manifestation of its life an animated character. Importance of expression in the world of animation is a manifestation of its life an animated character. Use the data feature-point to capture facial movements, will be able to put the location of point features 3D models to follow the movements of the human face feature. To overcome facial deformation source with the character's face, Linear Blend Skinning basic methods need to be used so that the deformation process can still display the facial characters expressions were reasonable or natural. Using clustering data clustering as membership data each centroid as the area affected by the deformation. Transformation of linear deformation using LBS has a good ability in determine the amount of change in the new coordinate point in accordance with changes in human facial expressions. The change capable of to properly visualized in the form vertec or scatter-data or using a polygonal mesh. With these visualizations can be shown by good deformation.**

***Keywords*— *facial animation; linear blend skinning; liniear deformation; scatter-data; feature-point; mesh poligonal;***

## I. INTRODUCTION

Facial animation an important part in the 3D virtual world which is the process of moving the character's face in 3D according to the joint motion that follows the reference human face. For example, the movement of facial animation consists of blinking eye movements, the movement of the lips when speaking, the movement of facial skin when facial expression. Evocation expression in facial animation could use non-reference marker or markers. Marker used as the reference position of the movement is based on the feature-point motion on the face, in this case the position of the facial muscles. Whereas non-reference marker refers to techniques blend shape or 3D scanning. In this study, observations were made on the feature-point position as a reference point movement captures the facial skin to produce expression [1].

The expression is an important component in explaining the mood of a figure or characters. So that figure or characters can express themselves through facial expressions. This expression is non-verbal communication [2].

The process of facial expression, for example, in the initial expression is changed from standstill to pleased or happy expression there are changes in the location of point features on the face [3]. The change process resulted in the deformation on the surface of the face, particularly in areas affected by change due to movement.

Deformation in the face of a 3D model is unique and cannot be used directly for the other models. This specificity impact on the visualization process changes [4]. If desired change in instantaneous deformation on the face, it will require high computing computation and many memory resources.

This study uses a linear deformation, is linear blend skinning (LBS). This method is widely used because by having more computing simple and does not require high resource, so it is possible to be applied in the processing of instant or real-time.

## II. STATE OF THE ART

### A. *Facial Animation*

Facial animation is a process of motion on 3D models a realistic similar to human faces by displaying a wide range of emotion or expression [5]. *Facial motion capture database* is the data that shows the movement of facial expressions form a model or actor who has given a marker in the capture of the camera [6]. The action of a model or actor is doing a series of expressions like: silent, angry, very angry, scared, very scared, sad, very sad, surprised, very surprised, etc. Modeling of facial expressions requires a lot of cost and time, even with professional animators though. Therefore intuitive, easy and effective a facial expression system would be useful in a variety of industrial applications such as animated films and video games [6].

### *B. Feature Point*

Feature points are the points of samples used as reference in the movement or displacement data capture systems face like muscles, hinge and jaw. Featur points are used as a simplification in computing compared to perform 3D scanning that requires doing calculations at all points of the face. In this study, we use the marker's face as much as 33 markers placed on areas of the face (figure 1). The amount is based on the tool *OptiTrack*.

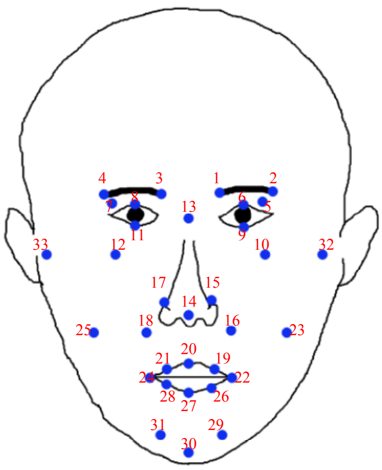



Figure 1: Feature Point Position

Considering that the target of the face consists of *feature-point*, so that through the movement of each point can be calculated according to the motion of *feature-point*, so that the muscles can be built for the model simulated the vector expression through muscle1 [6][7][8].

### *C. Clustering on 3D face model*

Mapping shells on facial animation requires special handling based on the characteristics of dimensions size and locations of the bones in supporting the establishment of the correct expression on the face. In most of the mapping manually specified area and carried out by the animators. The area associated with a number of changes that occur on the surface of a model's face as a result of the influence of the movement of the bone [9]. Each vertex forming facial expressions of 3D models selected as a cluster centroid and represented as motion area that number is adjusted by the number feature point in the motion capture data. By clustering the area of motion can be produced and simplified based 3D face models [10]. In mapping or grouping feature point is regarded as the centroid point using the relationship tighty neighbors as members of a cluster. Mapping applied clustering is used to obtain good results using a map of the orthogonal projection model [11]. Data matrix [3324x9] is the data matrix coordinate the membership of each centroid obtained from clustering algorithms through research, entitled Feature-Points Nearest Neighbor Clustering on 3D Face Models.

### *D. Linear Blend Skinning*

LBS is a framework in view of deformation [12][13]. In the process of calculating the deformation of any changes in motion must be made, particularly in applications such as games etc. LBS is used in animation facial expression as a means of controlling or deformation intuitive, through such an approach can be predicted in the formation of a surface deformation reasonable physical or natural and aesthetically [14]. In the process, the weight of each different Cartesian coordinates. Weights (w) has a value that is:

$$0 \le w \le 1 \quad (1)$$

in its membership value is 0 if a member of a group within the feature-point distance, so it does not change. Worth 1 if members of the group right at the point of change. (1)

The calculation of the weight (w):

$$w = 1 - \frac{n}{n_{max}} \quad (2)$$

n is the distance between the centroid coordinates with the coordinates of the cluster members. Nmax is the longest distance between the centroid coordinates with the coordinates of its membership. (2)

Calculation of deformation:

$$V_i^{'} = \sum_{j=1}^{m} w_j(V_i)\, T_j \binom{V_i}{1} \quad (3)$$

The equation can be be decomposed into:

$$V^{'} = MT \quad (4)$$

$V'$ a new vertex position, $w_j$ is the weight, $V_i$ an old vertex position, $T_j$ is the amount of transformation, and $M$ matrix merger between vertex position $V_i$ with vertex weights $V_i$. (3-4)

## III. PROPOSE METHOD

The focus of this research is the visualization process of deformation of facial expression on a 3D model generated from human model through the process of feature extraction are then synthesized to the 3D model using LBS.

### A. Schematic Diagram Facial Animation

This process is part of a global scheme facial animation which uses data retrieval sequesntial imagery. Sequesntial image is an image taken using a video camera, where the data is extracted each frame. So that these data have the data in a time sequence. After this process the data marker identified in the image data. Then extracted to generate 2D model data is used as reference targets registered vertexs. The next step is from an existing vertex on the model sought sequenstial correlation to the data specific to certain poses, such happy expression, anger, fear, sadness as the sample data. At the time of this synthesis process the data feature point is assumed as a marker of central movement of data, so that the initialization phase beginning segmentation area formed by points or features are generated using a clustering algorithm that has been done by the SG Gunanto, M. Hariadi and EM Yuniarno in a paper titled Feature-Nearest Neighbor Clustering points on 3D Face Models [10]. Results from these areas made the weight that will be use in consideration of deformation in a linear which will be adjusted to the distance and weight. Before the deformation data sequenstial each frame registered through 2D techniques to 3D Space Transformaton that has been done by Troy, Pranowo and S.G. Gunanto in a paper entitled "2D to 3D Space Transformation for Facial Animation Base on Data Marker"

[15] thus obtained can be in correlation to visualize based segmentation in the process of linear deformation which results in deformation perframe based on data from the camera catches sequesntial. For a more complete schematic diagram can be seen in figure 2.

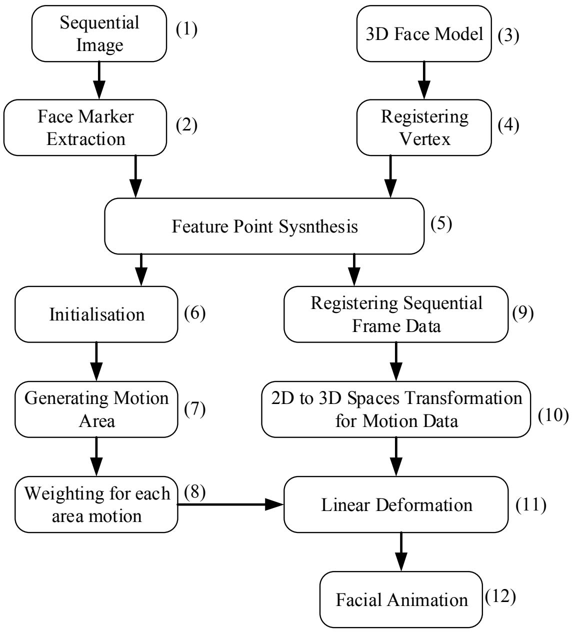



Figure 2. Skematik Diagram Facial Animation

In this study, we use a feature point on an actor's face as many as 33 feature points are placed in areas of the face. The number refers to the template *OptiTrack* motion capture arena. This choice is expected to produce changes in the deformation of better facial expressions.

In the early stages, namely image used as a source 2D marker will go through the process of extraction (face marker extraction) based marker / feature point that is planted on the face of an actor. From this process the data obtained in the form of matrix [33x2] 2D coordinates are xy coordinates. The following steps are the coordinate data will be embedded in a 3D avatar models according to the position that existed at the 2D marker is through the process of retargeting, then acquired 3D data in the form of Cartesian coordinates x y z.

## B. Linear Deformation Algorithm

The initial data is that the data input matrix [33x3] which is a 3D coordinate data expression is flat, the data matrix [33x3] which is an expression of 3D coordinate data happy / sad / scared, ΔF a calculation of the difference of the coordinate expression was happy with the coordinate expression flat. The next stage is to calculate the distance between the members of the centroidnya is nx = Membership coordinate the data matrix is reduced with a data matrix flat coordinate expression in accordance with centroidnya cluster. Once the distance is known, the next step is to calculate the weight of the equation (2). To determine the amount of deformation is the weight calculation * ΔF so it can be to calculate new coordinates after deformation is deformation summed with the old coordinates.

For more details on the algorithm calculating the deformation changes the face of the 3D model is built can be seen in figure 3:

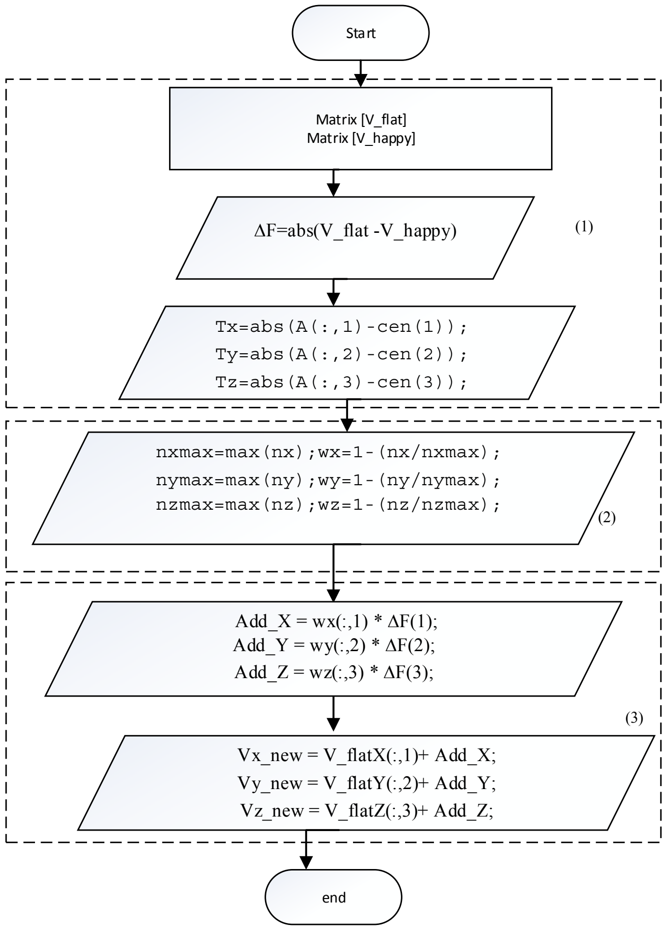



Figure 3. Deformation Calculation Algorithm. (1) Initialistion data, (2) the calculation of weights points, (3). The calculation of deformation.

In this paper the data extraction and segmentation feature point motion area is already known to refer to the paper entitled "Feature-Points Nearest Neighbor Clustering on 3D Face Models". Motion area or weight paint area will be used in this study as a local area deformation as input reckoning LBS. The local deformation will be processed on each cluster to a change feature point. Which as a feature point of reference is the result of retargeting. The following will explain how the calculations presented formulas used in this calculation:

Calculating the amount of change of coordinates centroid silent marker with marker centroid happy (eq. 5-7).

$$\Delta Fx = \|\mathrm{cx}_{\mathrm{old}} - \mathrm{cx}_{\mathrm{new}}\| \quad (5)$$

$$\Delta Fy = \|cy_{\mathrm{old}} - \mathrm{cy}_{\mathrm{new}}\| \quad (6)$$

$$\Delta Fz = \|\mathrm{cz}_{\mathrm{old}} - \mathrm{cz}_{\mathrm{new}}\| \quad (7)$$

Calculating the distance members against centroidnya (eq. 8-10). Through the clustering of data will be obtained coordinates of each member of the centroid.

$$\mathrm{d}_{\mathrm{x}} = \|\mathrm{x}_{\mathrm{old}} - \mathrm{x}_{\mathrm{new}}\| \quad (8)$$

$$d_y = \|y_{old} - y_{new}\| \quad (9)$$
$$d_z = \|z_{old} - z_{new}\| \quad (10)$$

Once the data is known distance data, it is necessary to count the amount of weight for each axis kartesiannya $w_x, w_y, w_z$

$$w = 1 - \frac{n}{n_{max}} \quad (11)$$

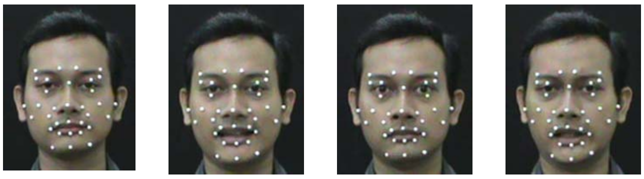
In determining the proportional occurrence of a change, must adapt to the axis kartesiannya. To obtain indigo changes per sub coordinates:

$$Deformation = w * D \quad (12)$$

The addition is used as a reference in generating the new coordinates, by adding the old coordinate matrix according to the coordinate axes.
Through the process of the trial results will be visualized with a 3D face model lowpoligon

## IV. RESULT AND DISCUSION

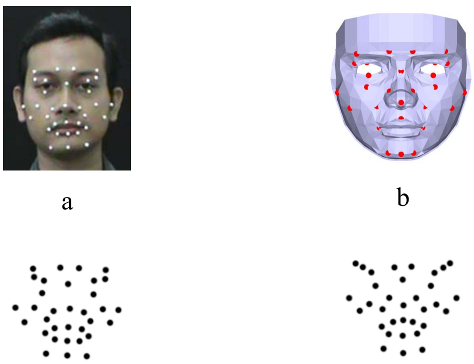
LBS testing to show the results of visualization expression deformation generated 3D model of the human model. Sequesntial image is an image taken using a video camera, where the data is extracted each frame in figure 4.



a. Flat b. Happy c. Anggry d. Disgust

Figure 4. Sequential image of many expressions

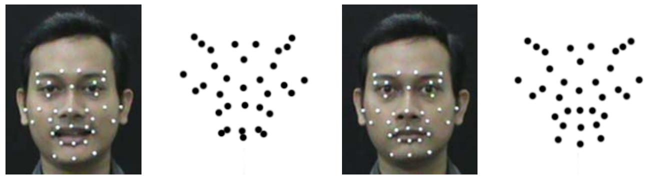
Figure 5. Showing a pair of training data that consists of a source face marker extraction (2D image) with 33 marker as input, in which the image has a marker information in coordinates (x, y) and the feature points of the 3D face model in the coordinates (x, y, z). At the training data, the source face and the target face shows flat expression.



a b c d

Figure 5. (a,c) Face Marker Extraction. (b,d) 3D face Model with Re-traget Vertex.

The next step is from an existing vertex on the model sought sequenstial correlation to the data specific to certain proses, such happy expression, anger, fear, sadness as the sample data figure 6.



a b c d

Figure 6. Face Marker Extraction with Re-traget Vertex.

At the time of this synthesis process the data feature point is assumed as a marker of central movement of data, so that the initialization phase beginning segmentation area formed by points or features are generated using a clustering algorithm. Clustering result from 3D human facial model with vertex 3324 figure 7(c).

a b c

Figure 7. Face Marker Extraction with member of clustering with vertex 3324.

Results from these areas made the weight that will be use in consideration of deformation in a linear which will be adjusted to the distance and weight. After performing weighting processing of the data within the membership with the centroid, then obtained the value of the amount of changes to the new Cartesian axis of calculation of LBS. Testing is done by visualizing using vertex data is obtained from LBS. Based on the results of the LBS visualization basic expressions; happy, angry, disgust, surprise, and fear, can be visualized with a polygonal mesh to form a 3D face models.

The results obtained are presented in Table 1, which shows the sample value of the coordinates (x, y, z) members of clustering, the value of the coordinates (x, y, z) Clustering.

Table I. Coordinates member of clustering

| Point | Coordinats member of clustering | | | Centroid Point | | |
|---|---|---|---|---|---|---|
| | X | Y | Z | X | Y | Z |
| 1 | -0,0146 | 0,2084 | 0,1192 | -0,0150 | 0,2096 | 0,1195 |
| 2 | -0,0150 | 0,2096 | 0,1195 | -0,0150 | 0,2096 | 0,1195 |
| 3 | -0,0281 | 0,2096 | 0,1170 | -0,0150 | 0,2096 | 0,1195 |
| 4 | -0,0203 | 0,2044 | 0,1166 | -0,0150 | 0,2096 | 0,1195 |
| 5 | -0,0130 | 0,2027 | 0,1164 | -0,0150 | 0,2096 | 0,1195 |
| 6 | -0,0080 | 0,2052 | 0,1166 | -0,0150 | 0,2096 | 0,1195 |
| 7 | -0,0203 | 0,2044 | 0,1166 | -0,0150 | 0,2096 | 0,1195 |
| 8 | -0,0080 | 0,2052 | 0,1166 | -0,0150 | 0,2096 | 0,1195 |
| 9 | -0,0146 | 0,2084 | 0,1192 | -0,0150 | 0,2096 | 0,1195 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 | -0,0339 | 0,2031 | 0,1111 | -0,0150 | 0,2096 | 0,1195 |
| | : | : | : | : | : | : |
| 120 | -0,0161 | 0,2367 | 0,1275 | -0,0150 | 0,2096 | 0,1195 |
| 121 | 0,0000 | 0,2217 | 0,1285 | -0,0150 | 0,2096 | 0,1195 |
| 122 | 0,0000 | 0,2367 | 0,1275 | -0,0150 | 0,2096 | 0,1195 |
| 123 | 0,0000 | 0,2589 | 0,1265 | -0,0150 | 0,2096 | 0,1195 |
| 124 | 0,0000 | 0,2589 | 0,1265 | -0,0150 | 0,2096 | 0,1195 |
| 125 | 0,0000 | 0,2367 | 0,1275 | -0,0150 | 0,2096 | 0,1195 |
| 126 | 0,0000 | 0,2367 | 0,1275 | -0,0150 | 0,2096 | 0,1195 |
| 127 | 0,0000 | 0,2217 | 0,1285 | -0,0150 | 0,2096 | 0,1195 |
| 128 | 0,0000 | 0,2367 | 0,1275 | -0,0150 | 0,2096 | 0,1195 |

Table I and II We use one sample with the centroid coordinates -0.0150, 0.2096, and 0.1195 the number of membership has 128. From the table I and II. From start point coordinates and wights LBS changes occour.

Table II. New Coordinates

| Point | W (wights) | | | New Coordinates | | |
|---|---|---|---|---|---|---|
| | X | Y | Z | X | Y | Z |
| 1 | 0,9832 | 0,9755 | 0,9808 | -0,0047 | 0,2143 | 0,1269 |
| 2 | 1,0000 | 0,9998 | 0,9963 | -0,0050 | 0,2157 | 0,1272 |
| 3 | 0,5068 | 0,9994 | 0,8178 | -0,0230 | 0,2157 | 0,1234 |
| 4 | 0,8008 | 0,8944 | 0,7854 | -0,0123 | 0,2098 | 0,1227 |
| 5 | 0,9221 | 0,8598 | 0,7714 | -0,0037 | 0,2079 | 0,1224 |
| 6 | 0,7348 | 0,9105 | 0,7832 | -0,0006 | 0,2107 | 0,1227 |
| 7 | 0,8008 | 0,8944 | 0,7854 | -0,0123 | 0,2098 | 0,1227 |
| 8 | 0,7348 | 0,9105 | 0,7832 | -0,0006 | 0,2107 | 0,1227 |
| 9 | 0,9832 | 0,9755 | 0,9808 | -0,0047 | 0,2143 | 0,1269 |
| 10 | 0,2888 | 0,8687 | 0,3820 | -0,0310 | 0,2084 | 0,1141 |
| | : | : | : | : | : | : |
| 120 | 0,9580 | 0,4512 | 0,4115 | -0,0065 | 0,2394 | 0,1307 |
| 121 | 0,4334 | 0,7557 | 0,3378 | 0,0043 | 0,2263 | 0,1311 |
| 122 | 0,4334 | 0,4518 | 0,4115 | 0,0043 | 0,2394 | 0,1307 |
| 123 | 0,4334 | 0,0004 | 0,4853 | 0,0043 | 0,2589 | 0,1303 |
| 124 | 0,4334 | 0,0004 | 0,4853 | 0,0043 | 0,2589 | 0,1303 |
| 125 | 0,4334 | 0,4518 | 0,4115 | 0,0043 | 0,2394 | 0,1307 |
| 126 | 0,4334 | 0,4518 | 0,4115 | 0,0043 | 0,2394 | 0,1307 |
| 127 | 0,4334 | 0,7557 | 0,3378 | 0,0043 | 0,2263 | 0,1311 |
| 128 | 0,4334 | 0,4518 | 0,4115 | 0,0043 | 0,2394 | 0,1307 |

Figure 8. Process (a,b,c) Face Marker Extraction and 3D face Model with Re-traget Vertex. Process. (d,e,f) Face Marker Extraction with happy expression and 3D face model with deformation vertex. (g,h,i) Face Marker Extraction with disgust expression and 3D face model with deformation vertex.

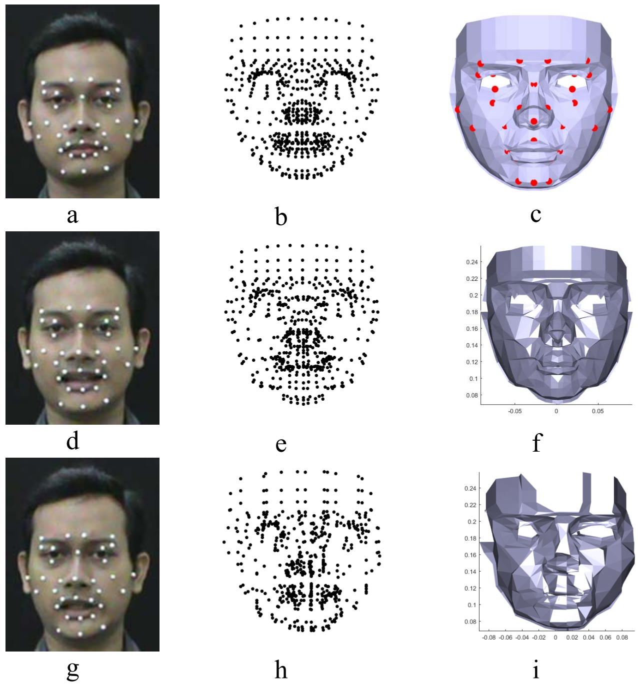



Figure 8. Deformation LBS applied to the image (a) Figure 2D of motion with capture markers as training with flat expression. (b) vertex data visualization member of clustering with vertex 3324. (c) visualization mesh low polygonal. (d) Figure 2D of motion with capture markers as training with happy expression. (e) 3324 vertex data visualization witch have been charged on the LBS algorthm. (f) visualization mesh low polygonal. (g) Figure 2D of motion with capture markers as training with disgust expression. (h) 3324 vertex data visualization witch have been charged on the LBS algorithm. (i) visualization mesh low polygonal.

## V. CONCLUSION

From the research above result has been capable of to properly visualized in the form of a scatter vertex or 3D data and using mesh. From the visualization indicated that deformation occurs well. On the development of subsequent research can be rebuilt with a similar algorithm for adding a clearer visualization, can be implanted with a texture is a model's face and using a polygonal mesh vertex hight greater than 3324 vertex of data with high specification computers or render farm.

## VI. REFERENCES

[1] S. Chin, C. . Y. Lee and J. Lee, "An automatic method for motion capture-based exaggeration of facial expressions with personality types," *Virtual Reality,* vol. 17, no. 3 , pp. 219-237, 2013.

[2] Q. Z. Beibei Li, D. Zhou and X. Wei , "Facial Animation Based on Feature Points," *TELKOMNIKA,* vol. Vol.11 No. 3, pp. 1697-1706, 2013.

[3] K. Yano and K. Harada, "A Facial Expression Parameterization by Elastic Surface Model," *International Journal of Computer Games Technology,* p. 11, 2009.

[4] O. O. Aina and J. J. Zhang, "Automatic Muscle Generation for Physically-Based Facial Animation," *Proceedings of the ACM SIGGRAPH 2010 Posters,* pp. 105-105, 2010.

[5] F. M, "Position-based facial animation synthesis," *Computer Animation and Virtual Worlds,* vol. 23, pp. 457-466, 2012.

[6] M. Botsch and O. Sorkine, "On Linear Variational Surface Deformation Methods," *IEEE Transactions on Visualization and Computer Graphics,* vol. 14, no. 1, pp. 213 - 230.

[7] B. J and C. C, "Adopting Virtual Production For Animated Filmaking," *7th Annual International Conference on Computer Games Multimedia and Allied Technologies,* 2014.

[8] Z. L and S. L. W, "Facial Animation with Motion Capture Based on Surface Blending," *GRAPP,* vol. AS/IE, 2007.

[9] S. G. Gunanto, M. Hariadi and E. M. Yuniarno, "Generating Weight Paint Area on 3D Cartoon-Face Models," *INFORMATION - An International Interdisciplinary Journal,* vol. 19, 2016.

[10] S. G. Gunanto, M. Hariadi and E. M. Yuniarno, "Feature-Points Nearest Neighbor Clustering on 3D Face Models," *The 4th International Conference on Information Technology for Cyber IT Service Management(CITSM),* 2016.

[11] S. G. Gunanto, M. Hariadi and E. M. Yuniarno, "Improved 3D Face fp-NN Clustering Using Orthogonal Face Map," *Advanced Science Letters,* vol. 22, 2016.

[12] A. Jacobson, I. Baran, J. Popovi´c and O. S. Hornung, "Bounded Biharmonic Weights for Real-Time Deformation," *CommunicAtionS of the Acm,* vol. 57, p. 4, 2014.

[13] M. Botsch , M. Pauly , M. Wicke and M. Gross, "Adaptive Space Deformations Basedon Rigid Cells," *EUROGRAPHICS,* vol. 26, no. 3, 2007.

[14] A. Jacobson, I. Baran, L. Kavan, J. Popović and O. Sorkine, "Fast Automatic Skinning Transformations," *Proceedings of ACM SIGGRAPH,* vol. 31, p. 4, 2012.

[15] T. P. and S. G. Gunanto, "2D to 3D Space Transformation," *InAES 2016 – The 6th International Annual Engineering Seminar,* 2016.