A method of defining modeling data for representing 3D facial expression

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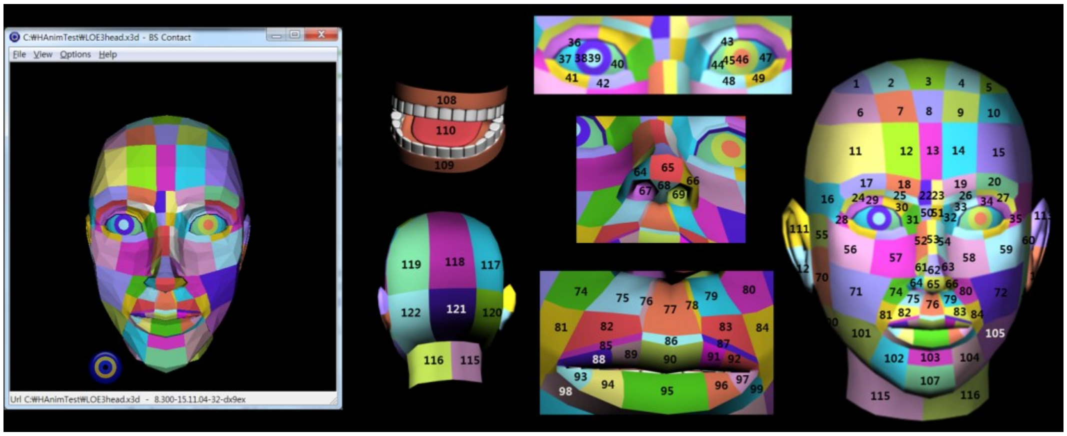

Figure 1: *Facial Regions for LOE 3 Facial Landmarks and Animation*

Abstract

This paper presents a method of facial modeling that provides for realistic facial expression and the exchange of facial models between systems and between applications. In this method, the surface of a face is divided into various connected regions, each with its own specific landmarks. The landmarks are used for generating facial expression. In addition, three levels of facial expression are defined which map to various levels of detail. This paper describes the development of facial animation standards based on H-Anim in the standardization groups of ISO/IEC JTC 1/SC 24 and the Web3D Consortium[ISO/IEC 2006]

Keywords: humanoid animation, 3D facial modeling, 3D facial animation, facial expression, 3D facial landmarks, head modeling

Concepts: • **Computing methodologies ~ Graphics systems and interfaces;** *Graphics file format;*

1 Introduction

Facial animation using skeleton and muscle is generated by controlling the vertices of a facial shape with anatomical muscles[Parke 1974]. This allows for realistic animation but requires very precise analytic models and time-consuming execution. Facial animation using motion capture allows for realistic animation, but has the disadvantages of requiring expensive capture devices and that it is not easy to generate a goal directed expression. Facial animation using deformable shape describes the change of each vertex with deformation energy functions and generates expression by optimizing the energy. It can result in good quality animation, but is a time-consuming optimization. Facial animation using deformation has two steps. Step one is to efficiently represent positions of various vertices varying nonlinearly using small data, which comprise facial shape. Step two is to recover original expression animation using the representation method in step one. In this paper, region based modeling for facial animation is the focus so that positional change in facial vertices can be maintained and analyzed when generating animation

2 Facial Modeling Using Region Partitioning

A facial feature point is arbitrarily selected in order to partition a face model. It can be any point selected by a user or a marker point that can be used for facial motion. In this research, a face model consisting of 23,725 vertices and 45,968 polygons is used for partitioning facial regions. There are three methods to partition regions of an entire face from feature points: repetitive region expansion, PCA (Principal Component Analysis) based region partitioning[Sattler at al. 2005], and a hybrid method that combines repetitive and PCA based partitioning. Our facial region partitioning is based on the hybrid method.

In repetitive region expansion, a set of regions is determined by selecting a feature point per region and then inserting directly connected vertices into the region. Then, the entire face is divided into the same number of regions as there are feature points, with all corresponding vertices included in one of the regions. This method does not consider the motion of facial vertices and therefore may cause errors when defining expression since facial regions may change according to the motion of feature points. PCA is an analytic method that can be used to determine some tendency from a large set of data. For N vertices, animation during F frames is represented as the following matrix A:

$$A = \begin{bmatrix} v_{1,1} & \dots & v_{1,F} \\ \dots & \dots & \dots \\ v_{N,1} & \dots & v_{n,F} \end{bmatrix} \qquad (1)$$

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For the transpose matrix of the matrix by exchanging rows and columns, partitioned regions from the initially selected feature points can be obtained by clustered PCA. The process of accomplishing clustered PCA: a) Select each center for regions arbitrarily. b) For each vertex, assign to it the nearest center vertex. c) Each new region center is calculated with the average of vertices in each region. d) For each region, a basis-vector is calculated using PCA. e) Steps b to d are repeated until the region of the vertex does not change any further, or until the error does not change within a limit. Figure 2 shows the result.

Figure 2: *Facial regions partitioned using clustered PCA*

Although the PCA method for animation data provides an optimal result for region partitioning, it does not reflect the result of selecting feature points. The hybrid method, combining repetitive region expansion and PCA based partitioning, basically expands regions repetitively based on an initial feature point, and determines if boundary vertices are sent to other regions by applying PCA repetitively. Because the hybrid method partitions depending on initial feature points without considering animation, partitioned regions reflect the feature points well and linear recovery with PCA has few errors. With the hybrid method, a stable region partitioning result can be obtained with a small number of repetitions(Figure 3). The hybrid method divides regions faster than PCA and represents the motion of regions better than iterative clustering.

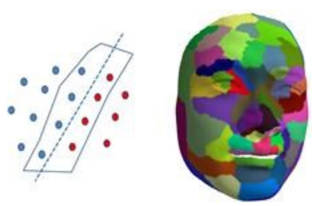

Figure 3: *Boundary vertices to be reorganized by the hybrid method (at left), facial regions resulting from partitioning using the hybrid method (at right)*

3 Definition of Facial Expression Animation Based on Region Partitioning

In this research, a facial model is partitioned into regions, and facial expression is generated by analyzing and representing the motion of center points (feature points) for each region. In order to obtain animation information for all vertices, a small number of selected vertices are used with small error ranges to represent the animation. The algorithm for the animation is as follows: a) Select a representative vertex for a facial region. This can be a feature point or selected with a marker. b) Calculate 3D MVC (Mean Value Coordinate) for internal vertices to boundary vertices[Ju et al. 2005]. c) Calculate a transformation matrix that parameterizes the motion of boundary vertices with the motion of the representative vertices. d) For each region, the MVC coordinates and transformation matrices of internal vertices are saved. e) Record positions of the representative vertices for each frame.

From the definition of facial expression animation, positions of boundary vertices for all facial vertices are calculated with the transformation matrices according to the motion of feature points. Positions of internal vertices are finally determined while maintaining MVC values according to the calculated positions of the boundary vertices.

4 Definition of Facial Landmarks

In this research, the overall surface of the face is divided into various regions which are then used to generate facial expression animation using the hybrid method described previously. In order to exchange region models and animation between applications and between systems, facial region landmarks are necessary. These landmarks must be defined with anatomical terms so that use of the facial models is applicable in areas such as medicine, health, or dermatology. In this paper, the terms for the regions of a face model are defined based on the naming of a head model by Molenda et al., 2010. In addition, three levels of expression (LOE) have been defined to represent facial models based on the desired complexity of expression. For the most detailed expressions, the highest level of expression is represented by LOE 3 landmarks. At this level, an entire head consists of 122 regions, including face, head, ear, teeth, and tongue. For less detailed expressions, LOE 1 and LOE 2 are defined with 43 and 70 regions respectively. LOE 1 is used for simple expressions that include motion of the eyes, nose, and mouth. LOE 2 increases the level of detail by including the forehead and cheeks, along with the eyes, nose, and mouth from LOE 1.

5 Conclusions

In this paper, facial region partitioning and standardized facial models based on regions that can be used to represent facial expression animation have been described. In addition, LOE 1, 2, and 3 facial regions have been defined in order to generate standardized facial models depending on the complexity of detail in facial expression.

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