3D Facial Modeling by NURBS

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1 Introduction

The development of facial image modeling process that incorporates the use of Non-Uniform Rational B-Spline (NURBS) to create realistic facial image is presented in this paper. Existing methods of facial modeling which use polygon representation have some inherent problems because it is unavoidable to trade-off between storage and smoothness. NURBS provide sufficient degrees of freedom for smooth facial image modeling while using comparatively small number of control points. The proposed method yet reveals a promissing property while applying to facial image deformation and animation. Using of only small number of parameters implies that the number of control parameters we use in each frame of animation is small too. This topic will be disscussed in part of our consequence work. A brief discussion of facial modeling process using NURBS which avoids the problems mentioned above is given along with the experimental results.

2 Facial Modeling and NURBS

Facial modeling and animation have long fascinated computer graphics researchers, not only for the ubiquity of faces in the real world, but also for the inherent problems in creating surface deformations and expressive behaviors. Facial modeling and animation are inherently multi-disciplinary efforts. Within computer graphics, applications of facial simulations have greatly increased as workstation performance permits real-time display of the hundreds of polygons necessary for minimal realism. Recent progress in facial animation now promises to provide useful and capable tools for virtual environments, human-liked agents, entertainment, telecommunication, education, linguistics, psychology and medicine. Each of these fields has already applied various sorts of face models to aspects of research: as "talking heads", as computer-controllable experiment generators, and as plastic surgery mannequins. Even a passive face conveys a great deal of information. Social science tells us, we see and react to spicies, gender, color, shape, wrinkles, hair, decorations(lipstick,mascara),and so on. As we see the remarkable profits of using facial action in interactive user interfacing system, Many sorts of efforts and algorithms in this area have been developed. The present research is concerned with another approach to 3D facial modeling that is the using of Non-Uniform Rational B-Spline (NURBS) which is well known as excellent curves and surfaces evaluator. The following equations show the extensive degree of freedom in surface modeling by rational evaluators which utilize homogeneous coordinates and central projection as defined by the following equation.

$$x(t) = \frac{X(t)}{W(t)}, y(t) = \frac{Y(t)}{W(t)}, z(t) = \frac{Z(t)}{W(t)}$$

where X(t),Y(t),Z(t), and W(t) are all define in homogeneous coordinates. To translate from homogenous space to curve space involves dividing by W(t). In this case W(t) is called *weight* of that control point. This extensive degree of freedom provides many interesting properties to NURBS evaluator. Firstly, NURBS has ability to represent conic section exactly which was impossible with the non-rational forms. Secondly, it has extra local control because altering a weight associated with a control point has a direct effect on the curve near the control point, thereby supporting intuitive modification. NURBS still have more degree of freedom than uniform B-Spline because its knots can be located non-uniformly. NURBS curve evaluator is defined by

$$\mathbf{C}(t) = \mathbf{H}\{\mathbf{C^w}(t)\} = \mathbf{H}\{\sum_{i=0}^{n} N_{i,p}(t)\mathbf{P_i^w}\}$$

$$= \frac{\sum_{i=0}^{n} N_{i,p}(t)w_i\mathbf{P_i}}{\sum_{i=0}^{n} N_{i,p}(t)w_i}$$

where:

- p is the degree of the curve.
- $N_{i,p}$ are the B-Spline basis functions.
- $\mathbf{P_i^w}$ represents a homogenous control point.
- $\mathbf{P_i}$ represents a curve space control point.
- w_i is the last ordinate of the homogenous point $\mathbf{P_i^w}$. It is called the weight of control point $\mathbf{P_i}$

The basis functions are defined by

$$N_{i,0}(t) = \begin{cases} 1 & if\ t_i \le t \le t_{i+1}\ and\ t_i \le t_{i+1} \\ 0 & otherwise \end{cases}$$

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$$N_{i,p}(t) = \frac{t - t_i}{t_{i+p} - t_i} N_{i,p-1}(t) + \frac{t_{i+p+1} - t}{t_{i+p+1} - t_{i+1}} N_{i+1,p-1}(t)$$

$T = \{t_0, t_1, .., t_m\}$. It is called a *knot vector* and the t_i's represent knot values. The equation for NURBS surface can be described by using a tensor product of two curve descriptions. e.g., A NURBS surface of degree (p,q) can be defined by

$$\mathbf{S}(u,v) = \mathbf{H}\{\sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,p}(u)N_{j,q}(v)\mathbf{P}^{\mathbf{w}}_{\mathbf{i,j}}\}$$

$$\frac{\sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,p}(u)N_{j,q}(v)w_{i,j}\mathbf{P}_{\mathbf{i,j}}}{\sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,p}(u)N_{j,q}(v)w_{i,j}}$$

where,

- $N_{i,p}$ and $N_{j,q}$ are B-Spline basis functions each with their own knot vector.
- $\mathbf{P}^{\mathbf{w}}_{\mathbf{i,j}}$ represent a homogenous control point.
- $\mathbf{P}_{\mathbf{i,j}}$ is a surface space control point, they form the control net of the surface.
- $w_{i,j}$ is the weight of the control point $\mathbf{P}_{\mathbf{ij}}$.

Our concept for 3D facial modeling by NURBS are shown in the diagram.

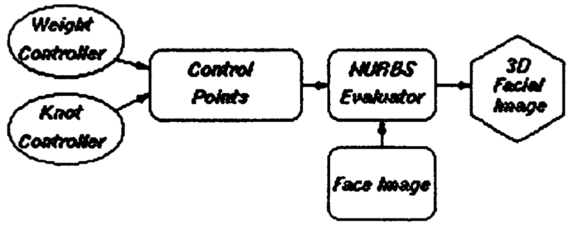

Figure 1: Diagram of 3D facial modeling by NURBS

The Main component for our surface modeling system is array of *control points*. The array is linked with *weight controller* and *knot controller* which adjust weight of control points and knot values respectively. The information of control point positions, weights, and knot values are fed to NURBS evaluator module to render 3D facial model. Meanwhile face image will be mapped to the rendered surface to enhance reality of model.

3 Experiment

An array of 7 × 7 control points has been used for modeling 3D facial surface in this experiment. We used cubic NURBS as an evaluator for 3D facial surface and texture mapping. The surface was created from scratch by manipulation of knot values both in horizontal and vertical direction, control points' position and its correspond control weight. Since we have high degrees of freedom in modeling the surface that are knot values, control points, and weight. There exist several ways and varieties of those parameter combinations for representation of an arbitary surface. The methods for adjusting those parameters in this experiment are considered heuristic ones but altering weights of control points and values of knots help modeling the surface to fit our desire shape. The results of this experiment are shown in Figure 2.

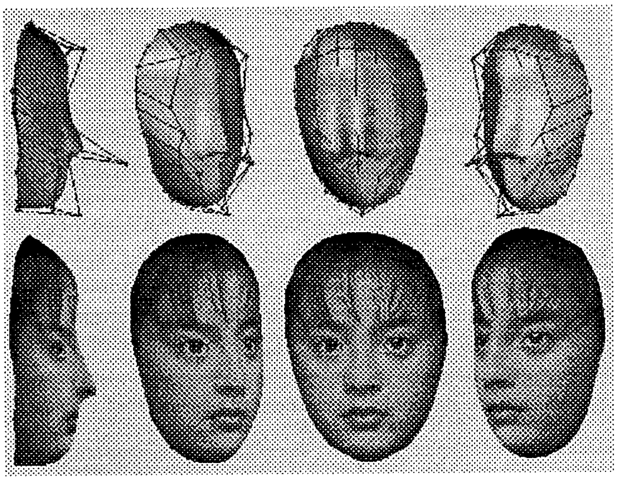

Figure 2: A 3D model of non-expression face modeled by NURBS and viewed from many angles

4 Conclusion

It is obvious that the existing of weight and knot parameters in NURBS ease modeling task remarkably compare to those conventional B-Splines. NURBS provide us a high degrees of freedom tool for modeling curves and surfaces to meet our desire shapes. Meanwhile, we should focus on how to manage those parameters in systematic way. A policy should be constructed to build an interactive sculpting tool for 3D surface modeling using NURBS. This will be issued in scope of our further research.

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