3D Facial Expression Modeling by Single NURBS Patch

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1 Introduction

Facial modeling has 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. 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. 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. This research proposes another approach to 3D facial modeling by using Non-Uniform Rational B-Spline (NURBS) which is well known as excellent curves and surfaces evaluator. With NURBS patch, we can construct realistic facial model relatively easily and economically with smaller set of data. Even with those constraints, the model is still smooth, comparatively wider dynamic range of view point, and capable of expressing facial features. Single NURBS patch model proposed in this research reveals possibility of deforming to various facial expression.

2 NURBS

NURBS are a true superset of Bézier representation. NURBS curves and surfaces become popular in modeling and surface design because they are capable of representing conic sections, quadric surfaces as well as free form modeling. A NURBS curve is defined by

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

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

where:

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

The basis functions are defined by

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

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

$T = \{t_0, t_1, .., t_m\}$. 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

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

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

where:

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

3 Modeling strategies

Rational forms of curve and surface evaluators are able to represent conic sections and quadric surfaces respectively. Bézier and B-Spline curves and surfaces have their own rational forms which is inducted by weights. We can also state that weights are extra

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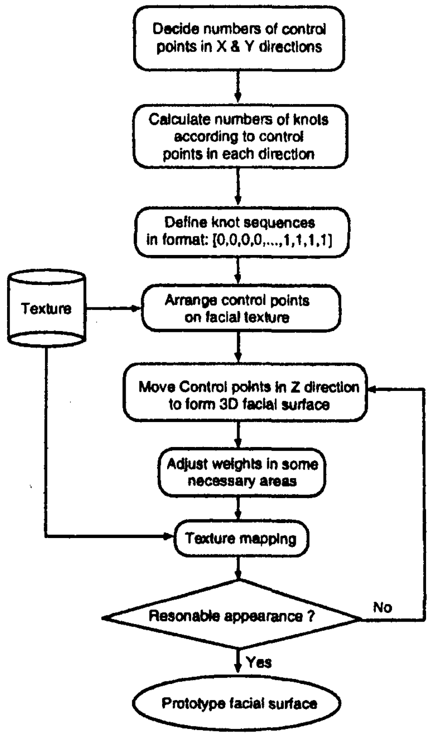

Figure 1: *Diagram of modeling steps.*

degrees of freedom. Especially, NURBS are rational form of B-Spline with non-uniform distributed knot vector. Designing steps are shown in figure 1. There are a lot of parameters to deal with in modeling a curves or surfaces which imply extended degrees of freedom. This is desirable in aspect of modeling capability but rather tedious in aspect of controlling. Knot values are fixed to the above sequences because we want to have bicubic surface forced to begin at first and end at last control points. Control points and weights are mainly adjusted according to image warping outcomes.

4 Experiment and Results

Figure 2: *Photos of neutral facial model and result of texture mapping.*

We built NURBS facial surface editor in our experiment. The prototype model was rendered on single NURBS patch. The patch consists of 13 × 9 control points. These number were derived from the experiment which compromise between model's quality and number of overall control points. The photos of neutral facial model are shown in figure 2. There are 20 Facial Action Units (FACS) in our NURBS editor. Each one is a series of key frames which cover negation of standard AU. These key frames are results of image warping of the original facial texture. Expressions on the face are derived from AUs combination. Some necessary AUs are weighted differently to form various kind of expressions. Figure 3 shows some basic expressions rendered by our expression editor.

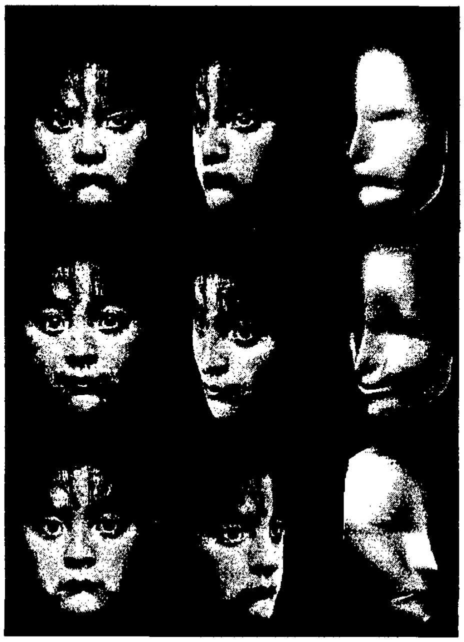

Figure 3: *Expression models: Anger, Happiness,and Sadness respectively from top to bottom.*

5 Conclusions

3D facial expression modeling by single NURBS patch was issued in this paper. The experimental results show that single NURBS patch is capable of facial expression modeling with comparatively small data. By using negations of standard AUs, we found that 20 AUs are adequate to generate basic expressions.

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