Improving Deformable Model Sharpness Feature Using NURBS

Rabiatul Adawiyah A.Rahman *, Abdullah Bade†, Daut Daman†, Mohd. Shahrizal Sunar†,
* Department of Computer Graphics and Multimedia, Faculty of Computer Science and Information System,
Universiti Teknologi Malaysia
81310 Skudai, Johor Darul Takzim, Malaysia.
Tel. +607-553-5315, fax. +607-5565044
*bee_hafiz@yahoo.com, †{abade, shahrizal, daut}@utm.my

ABSTRACT
Modeling deformation remains a problem in real-time application, especially in medical images segmentation. In critical medical application such as virtual surgery simulation, the realism and sharpness are important but it needs high computational cost. This problem has been considered by numbers of researcher. The deformable model is represented by Non-Uniform Rational B-Splines surface and applied to facial application and human body. In this paper, we proposed a previous hybrid NURBS parameterization technique to be implemented with deformable model. This technique use a minimum numbers of control point in NURBS, and able to generate a smooth deformable model. It will reduce the computational cost and give a sharp deformation model.

Keywords: NURBS curves; NURBS surface; Deformable Model; parameterization

1.0 INTRODUCTION
3D deformable model has been used widely in various applications and becoming critical especially in medical images simulation. In medical application, 3D deformable model has been used to diagnose and treatment of disease, virtual surgery planning and segmentation of human organs as its offered accurate and robust approach. Non-uniform rational B-splines (NURBS) surfaces have become a powerful method in modelling representation because of their ability and geometrical properties [1–3].

To achieve the realism of the model without sacrificing the processing resources remains a problem for many developers, though there are many researchers have carried out considerable works on this. The aim of this study is to propose a new parameterization for NURBS curves and surfaces interpolation and approximation. The NURBS parameter values must be choosing precisely because it affects the shape of the expected resulting NURBS curve/surface.

In this paper, a developed parameterization method is proposed for NURBS curves and surfaces interpolation and approximation based on universal parameterization and centripetal parameterization. The rest of this paper is organized as follows. Section 2.0, discussed some related works in deformation technique. Section 3.0 introduces NURBS curve surface formulations. In section 4.0 we defined the interpolation & approximation methods which we are going to deal with and the proposed parameterization method is defined. The framework of applying the method is presented in section 5.0 and followed by conclusion.

2.0 RELATED WORKS
NURBS have become standards tool in modeling due to its flexibility, stability and local modification properties. The technique has been employed to solve the drawbacks of other techniques and to optimize it's properties.

2.1 IMPROVING THE SHARPNESS OF THE MODEL
In 2007, Leal subdivide the fitting data into cluster by using Self Organizing Map and then the error fitting is minimizing and the representation of the sharp feature was improved by using an evolutionary strategy in each cluster to steadily obtain the weight of the NURBS [4].

2.2 REDUCING THE NUMBER OF NURBS CONTROL POINT
In order to reduce the number of control point without sacrificing the shape of the model, there are various approaches has been studied by researches [5, 6, 7,8,9].
Although the approaches has been proven to reduce the number of control point, but it has not been tested to improve the shape of deformable model.

3.0 NURBS FORMULATION

NURBS stands for Non-Uniform Rational B-spline. NURBS curve of degree \( p \) can be defined as follow[2]:

\[
C(t) = \frac{\sum_{i=0}^{n} w_i N_{i,p}(t) P_i}{\sum_{i=0}^{n} w_i N_{i,p}(t)}
\]

where, \( P_i = (x_i, y_i, z_i) \) are 3D control points, \( w_i \) are the associated weights with each control point \( P_i \) and \( N_{i,p}(t), i=0,1,\ldots,n \) are the B-spline basis functions defined over the knot vector \( U = \{a, a_1, a_2, \ldots, a_{p+1}, b_1, b_2, \ldots, b_m\} \).

B-spline basic function is given as:

\[
N_{i,p}(u) = \begin{cases} 
\frac{u - u_i}{u_{i+p} - u_i} N_{i,p-1}(u) & \text{if } u_i \leq u < u_{i+1} \\
\frac{u_{i+p+1} - u}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(u) & \text{otherwise}
\end{cases}
\]

And

\[
N_{i,0}(u) = \begin{cases} 
1, & \text{if } u_i \leq u < u_{i+1} \\
0, & \text{otherwise}
\end{cases}
\]

To obtain a suitable parameterization and the exact number of the control point is still a problem in order to get a sharp feature of a deformable model. To generate a smooth NURBS surface, using the traditional methods that are uniform, chord length and centripetal sometimes is not sufficient.

4.0 THE PROPOSED METHOD

The conventional parameterization methods are inadequate to generate a fair NURBS surface when applied to the design complex deformation objects. The NURBS deformation model is suggested to represent the object deformation with minimum number of control points without sacrificing the object shape.

4.1 THE HYBRID NURBS PARAMETERIZATION

The process of minimizing the number of control points is achieved by using the knot removal operation within pre-specified error tolerance (\( \varepsilon \)). The steps of the hybrid deformable parameterization method are summarized below.

Let \( C \) be any cross sectional curve whose control points \( P_i, i=0,1,\ldots,m \) and degree \( p \). The hybrid deformable parameterization can be obtained by first using centripetal method to choose an initial parameter values \( u_k \), and compute the averaging parameter knot vector \( U_{cp} \). Find the B-spline basis functions \( N_{i,p}(u_k) \) associated with each data point within each span index by using \( u_k \) and \( U_{cp} \). Assign \( N_i \) the maximum B-spline basis function in each span, Figure 1.

After that, the rational B-splines basis functions \( R_{i,p}(u_k) \) were calculate as given below if using rational form. Assign \( R_k \) the maximum rational B-spline basis function within the associated span index. The square root chord length between each consecutive point was compute, and finally computes the hybrid parameter values[10]. The whole process can be summarized as in figure 2.

**Figure 1: Highest B-spline Basis Functions within Span Indexes**
\[ R_{i,p}(u) = \frac{\sum_{j=0}^{n} N_{j,p}(u) w_j}{\sum_{j=0}^{n} N_{j,p}(u) w_j} \] (3)

**Figure 2:** The flowchart of the proposed method.

### 5.0 CONCLUSION

This work in manipulated NURBS curves and surface to present better images is at an early stage. We suggest that this new parameterization can maximize the number of control point without sacrificing the computational resources.

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