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Deformation of CAD Surface Models using Programming Approach: A Review

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Abstract— CAD models especially surface models are basically not easy to design and edit with 2- D based interfaces due to their three dimensional nature. Many researchers have presented their work on techniques for deformation of CAD surface models. Achieving greater control on the shape of deformation of surface models is thus a need. Many techniques are numerically not that much efficient and deforming complex surface models in real time is thus a difficult task.

An effort is made here to review papers based on deformation of CAD surface models critically and thus provide solution to these complex problem.

In this context model gains specific importance as it not only help in learning the factors associated with it but also will provide a direction for improvements. This paper makes an attempt to study various techniques to deform surface model in real time. The primary aim of this paper is to understand and enhance the important aspects. Thirteen models are reviewed in this paper. Each of them is representative of a different conceptual view about deformations. The organization of this paper is as follows: initially after highlighting the need for the present study, a generalized framework of the study is presented. This is followed by a brief discussion and a critical appraisal. Finally the agenda for future research is spelt out.

Index Terms—CAD: Computer Aided Design

I. INTRODUCTION

CAD models especially surface models are basically not easy to design and edit with 2- D based interfaces due to their three dimensional nature. Many researchers have presented their work on techniques for deformation of CAD surface models. Achieving greater control on the shape of deformation of surface models is thus a need. By using Shape functions, designers can specify the area of deformation, and also have greater controls on the shape of deformation. This technique is numerically efficient, and can deform complex surface models involving several thousand control points in real time. The ability to specify non planar 3D curves is of fundamental importance in 3D modeling and animation systems. Effective techniques for specifying such curves using 2D in-put devices are desirable, but existing methods typically require the user to edit the curve from several viewpoints.[1]

More powerful manipulation methods are available for surfaces and users can also apply them to curves, but these methods suffer from their indirect nature when specific free-form shaping is required. Recently introduced methods provide more direct control of a spline curve or surface without forcing the user to change representation. [2]

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II. LIETRAURE REVIEW

2.1 An Interface for Sketching 3D Curves

Jonathan M. Cohen etal, Symposium on Interactive 3D Graphics Atlanta GAUSA Copyright ACM 1999 I-581 13-082-1/99/04...pp-17-21

The Author has presented a method for specifying 3D curves with 2D input from a single viewpoint. The Author proposed here that the user first draws the curve as it appears from the current viewpoint, and then draws its shadow on the floor plane. The system correlates the curve with its shadow to compute the curve's 3D shape.

2.2 Constraint-Based Curve Manipulation

Barry Fowler etal, IEEE Computer Graphics & Applications, September 1993, pp-43-49

In geometric modeling geometric properties such as position, tangency, and curvature are more important. Manipulation of a point on the curve is very difficult due to less control over these geometric properties. Achieving control is easy sometimes at a specific point.

In case of NURBS same problem exist in varying degrees. The weights of rational curves offer additional shaping freedom, but again these weights are bound to control points. The Author suggested a generalize method for repositioning an arbitrary point on a curve (or surface) of arbitrary degree. The method permits direct manipulation of certain geometric properties at any selection of points on a curve of arbitrary degree and basis. This two-stage evaluation method speeds the process for interactive manipulation. The Author outlined a method for applying systems of constraints at one or more arbitrary points on a single or composite curve and describes a technique for the interactive application of these systems.

2.3 Direct Manipulation of Free-Form Deformations: William M Hsu etal, Computer Graphics, 26,2, July 1992, pp-177-184 Free-form deformation (FFD) is a powerful modeling tool, but controlling the shape of an object under complex deformations is often difficult. 'The interface to FFD in most conventional systems simply represents the underlying mathematics directly, users describes deformations by manipulating control points. The difficulty in controlling shape precisely is largely due to the control points being extraneous to the object; the deformed object does not follow the control points precisely. In addition, the number of degrees of freedom presented to the user *can be* overwhelming. Here author has present a method that allows a user to control a free-form deformation of an object by manipulating the object directly, leading to better control of the deformation and a more intuitive interface for the user.

Author has illustrated four problems in manipulating deformations via control points.

1. Exact shape is difficult to achieve.

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2. Exact placement of object points is difficult to achieve.
3. Users unfamiliar with splines do not understand the purpose of the control points and the results of their movement.
4. The control points become difficult to manipulate when there are so many and they clutter the screen.

2.4 Exploring Interactive Curve and Surface Manipulation Using a Bend and Twist Sensitive Input Strip: Ravin Balkrishan etal, 1999 Symposium on Interactive 3D Graphics, Atlanta GAUSA,pp- 111- 118

Author has explored a new input device and a set of interaction techniques to facilitate direct manipulation of curves and surfaces. The input device, called ShapeTapem, is a continuous bends and twist sensitive strip that encourages manipulations that use both hands and, at times, all 10 fingers. Author explored this input and interaction design space through a set of usage scenarios for creating and editing curves.

2.5 Variational Surface Modeling: William Welch and Andrew Witkin

Author has presented a new approach to interactive modeling of freeform surfaces. Instead of a fixed mesh of control points, the model presented to the user is that of an infinitely malleable surface, with no fixed controls. The user is free to apply control points and curves which are then available as handles for direct manipulation. The complexity of the surface's shape may be increased by adding more control points and curves, without apparent limit. Within the constraints imposed by the controls, the shape of the surface is fully determined by one or more simple criteria, such as smoothness. This method for solving the resulting constrained variational optimization problems rests on a surface representation scheme allowing non uniform subdivision of B-spline surfaces. Automatic subdivision is used to ensure that constraints are met, and to enforce error bounds. Efficient numerical solutions are obtained by exploiting linearities in the problem formulation and the representation.

The most basic goal for interactive free-form surface design is to make it easy for the user to control the shape of the surface. Traditionally, the pursuit of this goal has taken the form of a search for the "right" surface representation, one whose degrees of freedom suffice as controls for direct manipulation by the user.

The control mesh approach is appealing in large measure because the surface's response to control point displacements is intuitive: pulling or pushing a control point makes a local bump or dent whose shape is quite easily controlled by fine interactive positioning. Unfortunately, local bumps and dents are not the only features one wants to create. For example, almost anyone who has used a control mesh interface has had the frustrating experience of trying to make a conceptually simple change, but being forced in the end to precisely reposition many control points to achieve the desired effect. This sort of problem is bound to arise whenever the controls provided to the user are closely tied to the representation's degrees of freedom, since no fixed set of controls can be expected to anticipate all of the users' needs.

The work here represents an effort to escape this kind of inflexibility by severing the tie between the controls and the representation. The model we envision presenting to the user is that of an infinitely malleable piecewise smooth surface, with no fixed controls or structure of its own, and with no prior limit on its complexity or ability to resolve detail. To this surface, the user may freely attach a variety of features, such as points and flexible curves, which then serve as handles for direct interactive manipulation of the surface.

Formally, this approach entails the specification of surfaces as solutions to constrained variational optimization problems, i.e. surfaces that extremize integrals subject to constraints.

2.6 Haptic Manipulation of Virtual Mechanisms from Mechanical CAD Designs:

Ali Nahvi etal, Proceedings of the 1998 IEEE International Conference on Robotics& Automation Leuven, Belgium. May 1998, pp – 375-380

A haptic display system is presented here for manipulating virtual mechanisms derived from a mechanical CAD design. Links are designed and assembled into mechanisms using Utah's Alpha.1 CAD system, and are then manipulated with a Sarcos Dextrous Arm Master. Based on the mechanism's kinematics and the virtual grasp, the motion of the master is divided into motion of the mechanism and constraint violation. The operator experiences the dynamic forces from the mechanism plus constraint forces.

2.7 Manipulation of CAD surface models with haptics based on shape control functions:

X. Liu, etal, ELSEVIER, Computer-Aided Design 37 (2005) 1447–1458

This paper discusses a technique for the deformation of CAD surface models with haptic interaction based on shape control functions. With the technique, designers can use a haptic interface to directly touch a native B-rep CAD model, and deform it in real-time by pushing, pulling and dragging its surfaces in a natural 3D environment. The deformation is governed by shape control functions. By using the shape functions, designers can specify the area of deformation, and also have greater controls on the shape of deformation. This technique is numerically efficient, and can deform complex surface models involving several thousand control points in real-time. The haptic-based deforming approach gives designers greater flexibility for the manipulation of complex CAD surfaces. But the accuracy of deformation of control points here merely depends on haptics based deforming approach.

2.8 Generation of CAD Surfaces by using Cubic Spline Curves: K. A. Awan

The latest computation techniques made it possible to simulate complex sculptured surfaces for CAD/CAM applications. The design of mechanical components is becoming more and more complex with the advancement in the speed and the power of computers.

In this research work a cubic spline curve generation algorithm is developed and implemented in a CAD system called Design and Manufacture of Complex Surfaces (DMCS). The technique generates cubic spline curves and these curves are integrated to generate complex surfaces. The cubic spline interpolation technique is developed for CAD applications which require exact shape of the objects. The surfaces produced have enough geometrical information like position, tangent/normal, and curvature so that they may be used in CAM applications. The system is capable of generating and editing the complex surfaces and then producing manufacturing information in CAM package. In this paper complete mathematical algorithm for the cubic spline interpolation technique is given. The working of the DMCS system is also presented by using a case study.

2.9 Surface Deformation Using the Sensor Glove: Lizhuang Ma

Intuitive 3D surface control and deformation are crucial to CAD/CAM. To do this in a virtual environment, however, the technique must be very efficient. A common method for shape deformation is the free-form deformation (FFD) method, in which the complete object is deformed by deforming a 3D grid of the object. In this paper, author has proposed an intuitive method for surface deformation based on deforming a hand surface, which is basically a bicubic B-spline surface interpolating or approximating key data points of a sensor glove. By setting up a corresponding mapping between the virtual object being deformed and the hand surface, the object can be deformed with the control of the sensor glove. As the user flexes his/her fingers, the object changes its shape accordingly. For local deformation, author has introduced a region filter function which imposes locality on the deformation.

The new algorithm is made efficient through incremental update. It is also intuitive as if the user were using his hand to deform the object directly.

2.10 Constrained shape modification of cubic B-spline curves by means of knots

I. Juha etal, ELSEVIER, Computer-Aided Design 36 (2004) 437–445

The effect of the modification of knot values on the shape of B-spline curves is examined in this paper. The modification of a knot of a B-spline curve of order k generates a one parameter family of curves. This family has an envelope which is also a B-spline curve with the same control polygon and of order k Applying this theoretical result, three shape control methods are provided for cubic B-spline curves, that are based on the modification of three consecutive knots. The proposed methods enable local shape modifications subject to position and/or tangent constraints.

These methods are excellent tools in design systems to create new objects, but the modification and shape control of the existing objects are also essential. The data structure of a B-spline curve of order k is simple as this consists only of control points and knot values and for rational B-spline curves weights have to be specified in addition. Thus it can be concluded that shape control methods can modify such curves only by altering these data.

2.11 Learning nurbs through s-cad:

Abdul Rahman Abdullah, Malaysian Journal of Computer Science, Vol. 10 No. 1, June 1997, pp. 81-85

S-CAD software provides most of the functions normally available in CAD systems. This paper introduces the NURBS entity, e.g., the degree value, the knot vector, the control points and weight of control point. Consequently the paper discusses the learning and understanding of this entity using the SCAD. Morphing Rational B-spline Curves and Surfaces Using Mass
Distributions

2.12 Tao Ju: 1 Eurographics 2003

A rational B-spline curve or surface is a collection of points associated with a mass (weight) distribution. These mass distributions can be used to exert local control over the morph between two rational B-spline curves or surfaces.

Here author has proposed a technique for designing customized morphs by attaching appropriate mass distributions to target B-spline curves and surfaces. And also developed a user interface for this morphing method that is easy to use and requires no knowledge of B-splines on the part of the beginner.

Morphing transforms one target shape into another. Research on morphing techniques has cantered around two tasks: establishing a proper mapping between target shapes, and creating a path between corresponding vertices. Solutions to these problems have been proposed in the domain of polygonal meshes. Author considered morphing between target shapes that are represented by rational curves or surfaces. Author has more focused on the problem of interpolation between pairs of points with the same parameter on two rational B-spline curves or surfaces, although this technique is suitable for any rational representation.

2.13 Shape Modification of Bézier Curves by Constrained Optimization: XU Li

2002 Journal of Software, Vol.13, No.6, pp-1069-1074

Bezier curve is one kind of the most commonly used parametric curves in CAGD and Computer Graphics. Developing more convenient techniques for designing and modifying Bezier curve is an important problem. This paper investigates the optimal shape modification of Bezier curves by geometric constraints. A new method is presented here by constrained optimization based on changing the control points of the curves. By this method, the authors modify control points of the original Bezier curves to satisfy the given constraints and modify the shape of the curves optimally.

III. APPRAISAL AND FUTURE SCOPE

Even though we have made an effort to review papers based on deformation of CAD surface models critically and thus provide solution to these complex problem, a fair conclusion can be made that deformation of CAD surface models is not easier to achieve numerically and controlling the shape of complex problems merely depends on the accuracy. Algorithm based programming approach can be more convenient and useful for such type of deformations of CAD surface models.

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