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MANIPULATION OF PROFILE OF CURVE USING CUSUMA: A CURVE SURFACE MANIPULATION TOOL

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ABSTRACT

A novel tool, CUSUMA, for a generation of all complex surfaces used in many engineering applications based on computer-assisted design, is developed to strengthen all available CAD softwares so that curve manipulation is made easy for product design and development. The tool can be used for creating intricate surfaces by changing position of control points easily. Before actually modeling the designer can select any number of control points on the canvas and complete the shape of the desired object. The curve is first drawn using CUSUMA, A GUI, with the help of proposed Profile Curve Management Technique (PCMT) and then import it in any CAD software. The designer can add, remove and manipulate any number of control points to achieve the desired accuracy of shape in early product design stage. The ultimate aim is to generate the desired shape by plotting the model using the platform and PCMT and then manipulation of any number of control points in real time by pushing, pulling, dragging, adding and removing it.

Keywords: CUSUMA: Curve Surface Manipulation, GUI: Graphical User Interface, PCMT: Profile Curve Management Technique, CAD: Computer aided design

INTRODUCTION

In the mathematical subfield of numerical analysis, a B-spline, or Basis spline, is a spline function that has minimal support with respect to a given degree, smoothness, and domain partition. Any spline function of given degree can be expressed as a linear combination of B-splines of that degree. In computer-aided design and computer graphics, spline functions are generated as linear combinations of B-splines with a set of control points. B-spline curves generates a smooth curve through any number of control points but to generate a Bezier curve of the same quality of smoothness, several pieces of

Bezier curves are used to achieve accuracy [7]. Hence to generate a quality Bezier curve there is a need to develop a tool as it is not possible to generate a smooth quality curve without patches. To generate the smooth curve, designer needs to manipulate the control points.

The phenomenon of manipulation of curve using control point is explained in example. As shown in Fig.1, 'T' is a target point and 'S' is a start point in curve $P(t)$ with parameter t_s . It is required that curve should pass through the target point 'T'.

For that designer need to modify the curve and it is referred as shape modification by manipulation of control points. As number of control points are required to generate a curve, manipulation or deformation of these control points should be accurate and as expected by the designer. These manipulations are used enormously during interactive design.

Fig1: Local shape modification

In shape modification using manipulation of control points it is required to have good local control over the curve i.e. if one control point or vertices is moved to set location only some portion of curve segment should move or affected and not the bigger segment on the curve. The remaining portion of the curve should remain unchanged.

A surface under construction is usually composed of several NURBS surfaces known as patches as stated earlier. These patches should be fitted together in such a way that the boundaries are invisible.

In most of the applications it is well known fact that a single control point only influences those intervals where it is active and it is a highly desirable property which is referred as local support. In modeling, it allows the

changing of one part of a surface while keeping other parts equal. Adding more and more control points initiates better approximation to a given curve but it leads to more computation time. And once user adds control points on the curve it is expected that the shape of the curve remains unchanged.

If designer changes the position of control point then he loses the control over the shape of the curve which ultimately leads to unsatisfied form of surface. The designer wants total control over the shape while manipulating the profile curve. This is generally required in new product design and development in existing designs. To facilitate and improvement in product design processes, new methodologies and technologies which can support the existing computer aided design systems are required. Perhaps this should be need based product design in which further improvements in design is possible to enhance aesthetic view of existing products.

For example in car surface design greater flexibility is required in generating surfaces and if it could not be achieved it may lead to increase in cost and unsatisfied form of surfaces.

Therefore the present research work focuses on generation of controlled profile curves and thereby surfaces using PCMT.

REVIEW OF LITERATURE

As per the survey on Concept Design by a leading CAD software firm, reveals that the creator has more responsibility than influencer, executive and manager. The

creator of concept design shares 47 % role in concept design stage. This is because if creator don't start with a good concept, the product fails and that leads to lost market share, dissatisfied customers, squandered resources, and wasted time. To grab market share and to become successful, innovation in new products is thus a prime requirement. Most critical decisions about the products shape are finalized during concept design stage and exploring more design options during this stage is required to reduce the time spent. Most of the times designers use rendering tools during this stage than sketching tools and CAD tools. Respondents need to recreate the design many times before actually finalizing the shape only because their design tool formats are not compatible [6].

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 prime 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. [12]

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 [7]. CAD research into interactive and optimal surface placement is important for prototyping and design variation analysis [3].

Cohen J.M. et al. (1999) had demonstrated a new way to enumerate 3D curves by using 2D input from alone point of view. Their modeling system is based on curve sketching. As per this method the user first draws the curve as it looks from the existing point of view. Then the user sketches its shadow on the floor plane. The system associates the curve with its shadow to work out the 3D shape of the curves. This technique is more innate than the existing methods, as the existing methods require the user to edit the curve from several viewpoints. This modeling system pulls a user's talent with pencil and paper to generate more complex shapes.

Welch W. and Witkin A. (1992) demonstrated a novel method for interactive modeling of free-form surfaces which was developed at CMU. The modeler runs on Silicon Graphics Iris workstations. The modeler has the capability to manipulate

variational curves and surfaces through a variety of constraints and objective functions. The model has unlimited flexible surfaces with no fixed controls. This model allows the user to apply control points and curves which latter on accessible for direct manipulation of the surfaces.

Awan K.A. (2007) presented an algorithm for creating a cubic spline curve and implemented in a computer aided design system known as Design and Manufacture of Complex Surfaces (DMCS). This technique can create a cubic spline curves with geometrical information such as position, tangent/normal, and curvature. This geometrical information is useful for computer aided manufacturing applications. Thus the system has the capability to generate and edit complicated surfaces in turn yielding information required for computer aided manufacturing applications.

Ju T. and Goldman (2003) developed a method for designing custom-made morphs by appending appropriate mass distributions to target B-spline curves and surfaces. They also developed a user interface for morphing method that is easy to use and unskilled user with no knowledge of B-spline can be also use this method. Basically B-spline is a collection of points associated with weight distribution. These weights can be used to exercise local control over the morph among two B-spline curves.

Fowler and Bartels (1993) summarized a process of applying systems of constraints at one or more arbitrary points on a single or composite curve. They also provided an

analytic solution to these systems with examples. Their main aim was to apply the constraints to curves of arbitrary degree. Then the customer can interactively specify geometric properties based on curve's values and derivatives at selected points. Traditional methods of manipulation do not offer direct control over these geometric properties at an arbitrary point on the curve. But the authors have introduced methods that offer control of a spline curve or surface without forcing the user to change representation. This method offers direct handling of geometric properties at any selection of points on a curve of arbitrary degree and basis.

Sambhav et al. (2011) presented a scheme to design and develop shoe lasts as per the customer needs. The customization of the shoe last is done by surface modeling environment of CAD module using Surfacar V10 software. An optical scanner of type ATOS 3D Digitizer is used for scanning the foot and the nearest existing shoe last. Nowadays custom-made products are gaining more market share in compared to standard products. Hence, a lot of prospect is observed in the area of customizing footwear's. This scheme consists of seven steps in designing a custom-made shoe last. This customized process had been modelled mathematically and implemented through a program. This process consists of scanning and generation of point cloud data for foot and existing shoe lasts. Then a comparison is made between the point cloud data of the foot and the last. The selection of last is made to match the closest foot and over the last B-spline curves are generated with tangent continuity. Geometry

of the last is created by surface patches over the last. Lastly, the surface patches are diagnosed and modifying to fit the foot.

Hsu W.M. (1992) presented a technique which permits the customer to manipulate a free-form deformation (FFD) of an object directly with an ease. The major problem in deforming the shape of objects is due to control point manipulation. The change in position of control point also changes the shape of the object and desired shape is not obtained. Direct interface of FFD to traditional systems depends upon simple mathematics, where the customer manipulates the object through control points. Usually the deform object never follows the control points exactly thereby users finds difficult to control the shape precisely because of control points being superfluous to the object. Additionally, the number of degrees of freedom offered to the customer may be overwhelming. The fundamental thought behind this research is that the customer can move point of an object to the intended location by selecting a point on an object. This method has the capability to calculate the essential modification to the control points of the spline that will produce change.

New product design is the area where many European companies are concentrating and a survey is made related to problems companies are facing and trying to improve the controllability of their new product development. Sustainable improvement of any process requires controllability which is an attribute of an entity that states to which degree the entity can be controlled i.e. it is

the degree to which you can steer an object with control and attain a predefined goal. The primary improvement required in front end of the process i.e. first stage of Product development and secondary improvements are visibility and tracking of projects and communication [14]. The paper is based on the interviews carried out at leading European companies to improve product development.

The researchers have revealed that front end level is more important but managing the front end is considered to be difficult as recognizing the need and limitations in completing the task as per the requirement of customers need to be addressed and fulfil.

Design development, through risk combination, was recognized as a common theme in all recorded risk perceptions in product development. Greater risks can be perceived at conceptual stages only in new product development where resource commitment had not yet been made [9]. Engineering systems are increasing in scale, scope, versatility, competitiveness, and complexity. Designers simultaneously cannot considers every relevant aspect of any design. Once the design process progresses it might be possible that new information, ideas and technologies may enter into the market. This increases the work of design engineers and they will have to plan and design considering all aspects of design in advance. Also the resources required for this advance planning also requires ultra-modern tools which will produce optimum design. But designer has to break down the set of requirements into dimensions, constraints and features due to

unavailability of the tools which will satisfy the optimum design requirements.

This paper aims at investigating complexities involved with complicated shapes. Even though an effort is made 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 which will control the shape to the fullest and can be utilized for product design and development.

METHODOLOGY

A Graphical User Interface (GUI), CUSUMA is developed to control the shape of any surface by manipulating any number of control points. The designer will select required control points to draw the surface in first concept design stage only. With this application, any surface will be drawn with any number of control points and thus achieve a proper control over the shape. The complex geometries of typical design will now make manipulation possible.

The above concept will be achieved by following objectives.

1. To provide a computer-assisted system for designing of various shapes which involves direct manipulation of control points to achieve required shape.
2. To provide a tool that is compatible with any design related software and thus achieve control over any irregular shape.
3. To provide a technique that is efficient, and can draw any complex model involving several control points in real time and manipulate the model by removing or moving them.
4. To achieve deformation of models in computer aided design in real time application.

Fig 2 shows developed tool CUSUMA's canvas where profile curve will be drawn and finalized for importing it into any CAD software. Fig 3 shows Profile Curve Management using CUSUMA, where the profile curve is drawn. Fig 4 shows the CAD software where the profile curve is imported for further processing. Fig 5 shows the generation of duplication of curve in CAD and then final product is created.

Fig 2: CUSUMA Canvas

Fig 3: Profile Curve Management Technique

Fig 4: Importing the Profile in CAD

Fig 5: Duplicate Profile Generation in CAD

Figure 6: Comparison of Profile curve using (a) CUSUMA tool and (b) CAD software

Fig 6 (a) shows profile curve required to generate the object with control points and their associated tags which will be used for profile curve management in CUSUMA

while fig 6 (b) shows profile curve generated using CAD software.

The exactness of profile can be easily viewed in figures. The comparison of two profiles

clearly indicates that complicated profiles will be easily achieved in CUSUMA using Profile Curve Management Technique. This profile is also used in automobile gear pad

cover which is made up of rubber and use for protecting the gear handle bottom from dust or any foreign particle.

Figure 7: Generated Car Surface using CUSUMA PCMT

Fig 7 shows the car surface design model generated using CAD software with its profile drawn using CUSUMA having fully controlled profile curve management. This way one can generate any controlled profile for any surface design applications.

Furthermore, CUSUMA will facilitates designers to work closely with suppliers, manufacturing partners, and customers to get valuable input into the design chain and satisfy them.

With a broader vision, the collaborative efforts are required in available computer

aided design software and the proposed GUI which can be integrated to form collaborative product which supports applications for the whole product life-cycle.

The important features of CUSUMA are its simplicity and efficiency.

This simple and intuitive graphical user interface will be very much useful to the industry for improving product design and development in achieving desired shape and also it will save time in concept design stage.

CONCLUSION:

We know that, higher stress concentration occurs in the region with smaller radius of curvature which causes considerably increase in maximum stress. This area always create more hurdles to the designers. Hence designer requires to minimize stress concentration by avoiding higher curvatures. These high curvatures, in mostly aerodynamic shapes at the leading edge, needs to be addressed for optimum overall performance. In aesthetic surface design this also needs to be carefully handled, as direct manipulation of knots and control points is difficult as pointed by many researchers.

This ultimately leads to think critically about the direct manipulation problem in surface design. In view of this, CUSUMA is developed which is mainly based on profile curve management technique that allows the user to change shapes of surfaces in an intuitive way and convert them into reality.

Another area that can be greatly benefited is conceptual design. This modeling tool offers the freedom and flexibility to quickly formulate various concept ideas into reality.

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