Deformation of CAD surface models in real time environmnet for product design and development using CUSUMA tool

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Abstract— This paper provides a novel tool for a generation of complex surfaces based on computer-assisted design for various applications like aerodynamic shape design in airplanes, ships, cars, scooters, mopeds and also in industrial product design and development. The proposed tool can be used for generation of the intricate surfaces of any product by manipulating any number of control points.The product designer can select any number of control points before actually drawing and finalizing the shape of the desired object. The curve is first drawn using CUSUMA, A GUI and then import it in any cad software. The designer can add, remove and manipulate the control points to achieve the accuracy of desired shape in early design stage. In designing any complicated shape where accuracy plays an important role, the designer can use proposed profile curve management technique (PCMT). The ultimate aim is to generate the desired shape by plotting the model using the platform 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.*

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I. INTRODUCTION

Shape deformation through manipulation of control points have been an active area of research in geometric modeling, due to their massive applications in industrial design. The demand for ergonomics and aesthetics is increasing day by day. For increase in demand of more aesthetics by the end user, designers has to satisfy the requirements by changing the entire design or improvement in the existing design.

In computer graphics, parametric curves whose coordinates are given by splines are popular because of the simplicity of their construction, their ease and accuracy of evaluation, and their capacity to approximate complex shapes through curve fitting and interactive curve design.

During past two decades, industry has experienced major technological advancements in computer aided design. It actually aims to meet demands of globally competitive challenges in the field of product design and development.

Smoothness of the curve is the most important requirement of a synthetic curve. A complex curve consists of several curve segments joined together. As it is well known fact that Cubic Spline curves pass through all the data points and therefore they can be called as interpolated curves. Bezier and B-Spline curves do not pass through all the data points, instead, they pass through the vicinity of these data points.
NURBS curves also feature a scalar weight for each control point. This allows for more control over the shape of the curve without unduly raising the number of control points.
Curve based surface creation technique is a challenging task [1]. Predictable control, multiple values, Local control, Versatility and Continuity are the conditions which should be satisfied in mathematical splines. The complexity mainly depends on the control object, not the surface. A shape has to be stretched or sheared to satisfy the modeling constraints placed by the user.
Many existing softwares does not provide exact shape while manipulation or dragging of control points due to several limitations resulted in losing control over the shape of the curve. 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. 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.

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.

The present tools available can satisfy the designers need but due to global competency in all the products new tools for developing more controlled surfaces or curves are needed to be introduced.

II. 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 [5].

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. [6]

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 [8].

2.1 Shape and Surface Modifications:

Manipulation of a point on the curve is very difficult due to less control over these geometric properties however achieving control is easy sometimes at a specific point [4]. Fowler B. et al, has 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. Free-form deformation is a powerful modeling tool, but controlling the shape of an object under complex deformations is often difficult. 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. Hsu W.M. et al has suggested 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.

There are four problems in manipulating deformations via control points.

1. Exact shape is difficult to achieve.
2. Exact placement of object points is difficult to achieve.
3. Users are unfamiliar with splines do not understand the purpose of the control points.
4. Manipulation is difficult when there are several control points.

Balkrishan R. et al 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 bend 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.

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 method, in which the complete object is deformed by deforming a 3D grid of the object. In this paper, Lizhuang Ma, has proposed a method for surface deformation based on deforming a hand surface, which is basically a bi cubic 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.

The effect of the modification of knot values on the shape of B-spline curves is examined by Juha I. et al. 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. 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. XU L. 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.

Seidl et al in his patent has suggested a method and apparatus which facilitates direct manipulation of 3 D curve images on a computer display. With this method, a curve object is created and then generates a 3D virtual box image which

encloses a portion of selected curve image. But the success depends on correspondence between the manipulation of the virtual box and the curve image.

Hongwei L. has presented an iterative method to settle a problem in CAGD. Constructing a curve, interpolating the curve without solving a set of equations. The whole idea is based on iterative manipulation of control points and then forming a group of curves with higher precision. As even though the concept is new but it is not very useful since the whole idea is based on iteration formula. The only advantage is that the non-uniform B-spline curves (surfaces) generated with the iteration have few advantages, such as satisfying the NURBS standard, having explicit expression, gaining locality, and convexity preserving etc.

Chai et al in his patented work suggested that using 3D target curve Deformation of curved surface is achieved. It is achieved by deforming the object curve on the basis of calculated Variations of the control points. The invention has been made keeping in mind the drawing habits of a designer, when deforming the curved surface of a Nurbs model. Target curve is must to deform the curved surface.

2.2 Basics of Curves:

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 S-CAD [20].

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. The researcher 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. 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 [22].

2.3 Programming Approach:

Rath K. C. et al has focused on how parametric curves are important and extensively used in drawing complex parts such as automotive, aerospace and dies/molds. This paper presents a method to design a tool trajectory through MATLAB program. The .igs file gets converted into IGES reader for extracting the parametric data. The MTALAB program is generated for required cutter contact point for tool motion in the complicated spline trajectory. Author has prepared IGES READER software through programming platform and simulated result is executed as an output of MATLAB. Here author has linked CAD to CAM for complicated spline trajectory.

Salamon N. J. in his research paper focuses on mathematical fundamentals underlying computer methods in design. It is based on a course for students wherein they draw their creations mathematically. And develop interest in design applications using matlab as a tool.

2.4 Outcome of Review of Literature:

When a designer construct a surface at early design stage it is difficult to draw a rough shape of a surface and could not go with freewheeling approach easily. Also it is expected that a designer shall show as many sketches at the very early stage of design phases so that visualization is simpler.

This stage becomes an extremely important for any designer in today's competitive world. In early design stage, a designer has to consider the need of customer and there are set of considerations that should be taken into consideration once a concept design is finished.

Following activities needs to be supported:

1. **Trends in concept design**
2. **Design Modeling and Drawing**
3. **Exploration of choices**
4. **Data exchange**
5. **Feedback**

In entire design cycle it is very important to consider the capabilities to eliminate the recreation of design data. Selection of proper software is important to improve product design cycle with changes in recent CAD.

A need based software is thus a prime requirement in today's product design and development phase, which will facilitate the designer to create new designs or improvements in existing design for various industrial applications like aerodynamic shape design in aeroplanes, ships, cars, scooters and mopeds etc. and further it can be also used for various other applications like designing shape of any product.

III. METHODOLOGY

The aim of this paper is twofold:

(a) What are synthetic curves and difficulties in manipulating these curves and
(b) How to manipulate them in real time.

The above aims is accomplished in two phases. Firstly, main focus is on building a code and second focus is on creating geometries using the tool.

Fig 3.1 shows Traditional Software Development Life Cycle which is used for software development. New product design and improvement in design comes from Concept which is analyzed and then designing of software is done. This is then implemented and tested for debugging and then deployment is done on the system.

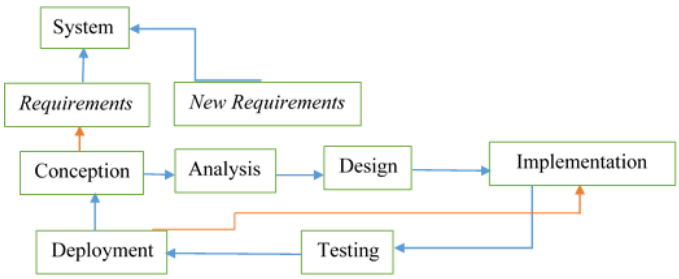

Fig 3.1: Traditional Software Development Life Cycle

Considering traditional software development life cycle, new product design and development life cycle is designed for better performance and total control over the curve manipulation.

Fig 3.2 shows new product design and development life cycle used for curve manipulation. Considering new product design requirements and or improvement in existing product design, CUSUMA will be useful for every designer to construct any shape of curve for better aesthetics view. The designer will have to simply draw the probable curve or surface using CUSUMA and then import the image in any image converter software. This image is then converted into .dxf extension for easy interface in CAD software. The required curve then can be used to complete the desired product design and its development in available CAD software.

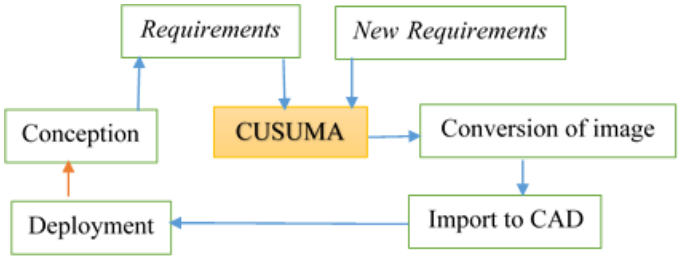

Fig 4.2: Product Design and Development cycle through "CUSUMA"

IV. CONCLUSIONS

Furthermore, this also 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 softwares and the proposed software which can be integrated to form collaborative product which supports applications for the whole product life-cycle. A proper interfacing is required for the success of proposed methodology.

In the aspects of enabling technologies, distribution is more fuelled by the development of IT, such as Java, .Net, Web, XML and Web service technologies, and collaboration is more driven by the design and development of effective collaboration mechanisms to facilitate human–human/human–computer relationships.

Our algorithm is effective and notably easy to implement, making it attractive for practical modeling applications. The important features of CUSUMA are simplicity and efficiency.

Designer will have to simply draw the probable curve or surface using CUSUMA and then import the image in any image converter software. This image is then converted into .dxf extension for easy interface in CAD software. The required curve then can be used to complete the desired product design and its development in available CAD software.

This is an important improvement for several industrial applications as the shape can be controlled by the designer who would simply sketch the controlled boundary curves of the desired product. This simple and intuitive user interface based on web based application will be very much useful to the industry for improving product design and development.

The software available for generating these surfaces can be customized for these applications or else this developed tool can be used to redesign the object which facilitates export of file in any CAD software for further improvements, if needed.

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