NURBS Modelling in Virtual Reality

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ABSTRACT

In the field of industrial design many efforts have been addressed to the development of easy to use software to improve the surface modelling phase. Commonly, softwares are very powerful in offering the user tools to create and modify 3D models, however, most of them lack two very important characteristics: 3D data input and real perception of the models. These characteristics are very important in many fields like that of the product style choice because, nearly always, models created by modelling software are three-dimensional.
To overcome these limits, in the work here presented, it has been developed a new methodology that make use of a 3D input device and a virtual reality system to create NURBS (Non Uniform Rational B-Spline) based three-dimensional models: using a 3D input device allows the designer to move his hands freely in the space to draw a curve or a surface, besides the use of a virtual reality system lets the user understand better a model in its three-dimensionality, perceiving it like real.

Keywords: CAD modelling, Virtual reality, NURBS geometries, 3D input devices

1.- Introduction

Designers main need is to transfer their concept sketch in a CAD model in a rapid and simple way so to allow evaluation of the alternatives and the beginning of the refinement work. The main limit in the use of classical CAD softwares is their bidimensionality. Usually, in fact, user makes use of two dimensional input and output devices, but this kind of systems does not help him in drawing and understanding three-dimensional models. To enhance the modelling phases some authors have studied the possibility of using the two hands manipulation technique [1-2], but this solution does not seem, actually, very simple because it is not completely integrated with the modelling environment. Others, to give the user a greater feedback feeling, have used haptic system to create CAD models [3]. Anyway all these attempts did not seem to be valid solutions.

Rapid growth of hardware and software technology performances during last years, allows new and unexpected enhancements in the field of computer aided modelling (CAD) techniques. The new paradigm of the virtual reality aided design (VRAD) has become one of main research field among scientific communities. Nowadays, to overcome the limit of traditional CAD softwares, it is possible take advantage of new visualization technologies, like virtual reality (VR) visualization systems and three-dimensional input devices. By means of these tools user is able to use his hands to draw, freely in the 3D space, its models and perceive them as real thanks to stereoscopic displays.

Many authors have dealt with the CAD – VR integration [4-5-6-7], some of these have also studied the possibility of a multi modal approach making use of gesture and speech recognition techniques [8-9].

In this work, the early stages of a new research project, developed at the virtual reality laboratory of the University of Palermo (Italy), concerning the carrying out of a platform, called CAMVIRE

(acronym of Computer Aided Modelling in VIrtual Reality Environment), that makes use of a virtual reality system and a 3D input device to create CAD models, are presented. In particular the three-dimensional models are based on non uniform rational b-spline geometries. The system is developed in C++ language and makes use of a graphic library and a geometric modelling kernel. User friendly tools to select, modify and manipulate are also developed.

2.- CAMVIRE system

CAMVIRE is an integrated system for computer aided modelling in virtual reality environments. It is being developed taking in mind the need of a fully integrated CAD system that increases its potential by using 3D output as well as 3D input techniques. In this system, as said, typical technologies of virtual reality environments, like 3D input and output devices, are integrated into a CAD architecture to give the designer an user-friendly and efficient tools to model in a three-dimensional space, allowing direct creation, selection and manipulation of the 3D models. CAMVIRE architecture is presented in figure 1.

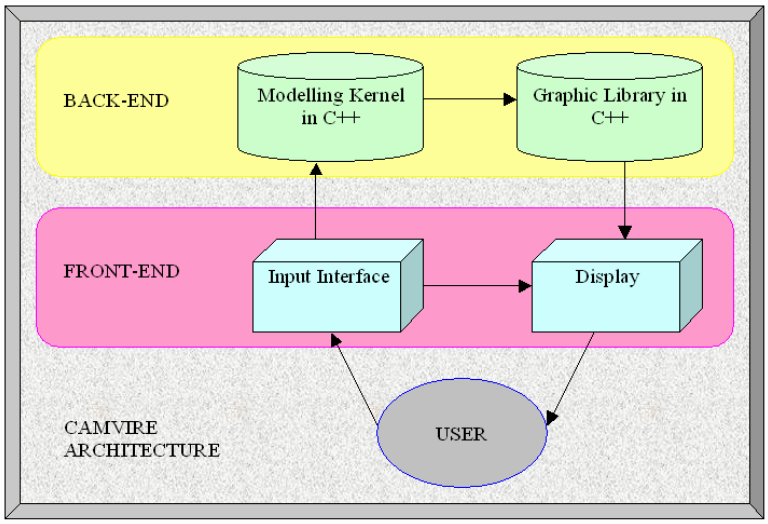

Figure 1 - Architecture of the CAMVIRE system

It is possible to divide it in two modules: a front-end and a back-end. The first one is the part that interfaces with the user, in fact by the display system the scene is visualized and by the input inferface it can be created and modified by the designer. The back-end part, instead, is not visible to the user; it manages, by the modelling kernel, the creation of the geometric primitives and its topological relationship, and displays in a stereoscopic mode, by the graphics library, the models and the others components of the scene, like menus and pointing object (wand).

CAMVIRE system makes use of the graphic library Open Inventor [10] and of the modelling kernel Open Cascade [11], both of them are written in C++ language.

Open Inventor [10] is a high level graphics library of objects and methods, written in C++, used for the creation of applications in the 3D graphics field. Open Inventor is founded on OpenGL [12]. The basic element in Open Inventor is the scene graph [13]. It consists of a collection of objects called nodes. Inventor supplies a large collection of re-usable nodes, represented by C++ classes, that can be derived and combined.

OpenCascade is a 3D modelling kernel that is formed of a library of objects in C++ and a set of development tools. It has many tools to create many geometries, like curves, surfaces and solids, and many classes to modify the created models, for example by mean of boolean operation.

CAMVIRE is based on non uniform rational b-spline (NURBS) geometry standard [14] because it is a very powerful method for the representation of models in parametric way. NURBS are used very often by the commercial CAD systems in order to represent very complex assemblies. Instead of using a few hundred of points in order to represent a surface, with a few control points (CPs) and some parameters it is possible to define a surface, in a very precise way, that can be, in dependence of the needs and requirements, approximated by a variable number of control points. The NURBS geometry is a standard for the designers that work in field characterized by free form objects and in which both the functionality and the shape (style) of the product are a very important side.

2.1 Hardware setup

CAMVIRE makes use of the most advanced commercial hardware systems:

- one SGI (silicon graphics) Onyx 4 workstation,
- one BARCO large screen display with two projectors,
- BARCO passive stereo glasses,
- one A.R.T tracking system with a tracked 3D-input device.

Onyx 4 by SGI is a modular architecture graphic workstation, it has two graphic pipeline, four microprocessors, four 160 GB hard disks and a 4 GB ram memory.

The visualization system is consisting of two BARCO projectors and a large screen (wall) display, which dimensions are about 3 x 2 m.

The A.R.T. optical tracking system has three cameras, a personal computer and a tracked 3D-input device called flystick (flying joystick – fig.2). The three cameras perceive spatial position of the tracked device by capturing reflected infrared light from flystick markers. Personal computer processes data received from cameras and sends them to the Onyx4 workstation by local network (LAN).

Figure 2 - Flystick

3.- CAMVIRE system functionalities

The system is accessible by a 3D pop-up menu (fig. 3), that can be reduced and moved in the working space, dragging it with the flystick. The avatar (wand) of the flystick and the 3D menu have been developed making use of the graphic library Open Inventor.

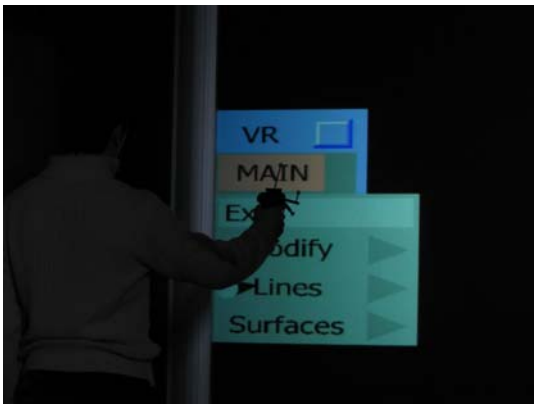

Figure 3 – 3D pop menu

CAMVIRE is continuously growing its potentialities that, actually, can be grouped in two kinds of functionalities: modelling and management tools. The firsts includes:

- creation of free form curves and surfaces,
- creation of straight lines and axes,

whereas the seconds comprises:

- 3D snapping,
- selection of objects in the scene,
- modification of geometric entities,
- deleting of objects.

3.1 Modelling tools

As said, using our system the designer is able to draw free form NURBS-based curves and surfaces. User needs only to wear glasses, push appropriate menu buttons and, in a simple and intuitive way, moving his arm in the three-dimensional space, can see its CAD models developing and looking as real. With CAMVIRE user can draw different kind of geometries:

- approximating curves,
- straight lines,
- freely extruded surfaces,
- predetermined extruded surfaces,
- revolved surface,
- loft surfaces.

For all different geometries, modelling phase starts with the picking of menu button related to the object to create; in this way, in fact, it is possible to manage user input in an object dependent way, with coherence and no ambiguity.

Models creation is developed by the geometric kernel whereas the graphic library is used to perform the visualization process. The geometric modelling kernel is consisting of Open Cascade and some geometric and topological algorithms developed just for this application. Input data are sent to the modelling kernel which creates, following appropriate rules, the requested geometries as C++ objects. From these the graphic library (Open Inventor) recovers all the necessary data, like number of control points and knot vectors [14], and displays the geometries in the workspace in stereoscopic way (fig. 4).

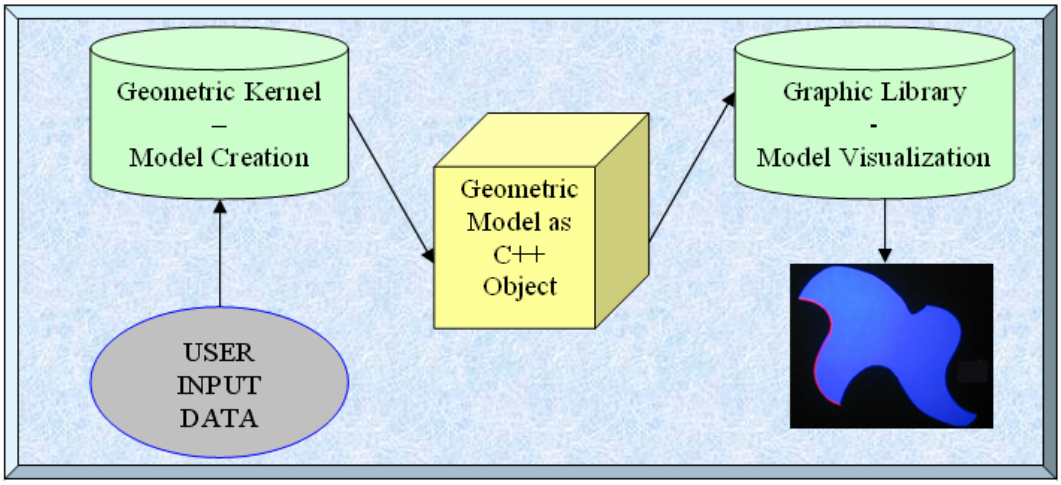

Figure 4 – Model creation and visualization process

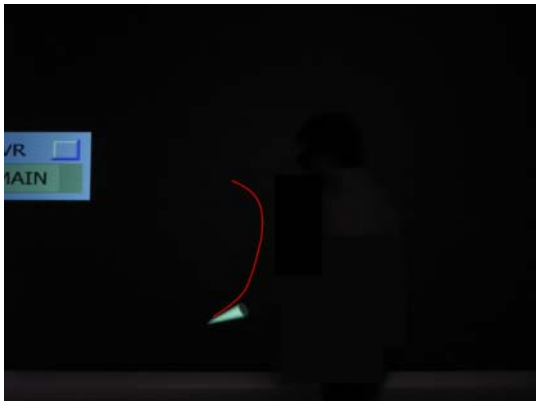

Figure 5 – Creation of a curve

After having selected the feature to create from the 3D menu, user can start drawing phase. Curves and surfaces are created according to the user arms movement in the space. Flystick spatial position, during the drawing phase, is processed by the modelling kernel to create different geometries. The sampling of the flystick spatial positions is made at constant time intervals, so to have a greater number of control points when, as usually happens, the shapes are more complex and the user movements to describe the geometries are slower. In such a way, there will be a better approximation for particularly curved geometries. For all the geometries the sequence of the knot vectors is predetermined (first and last values of the sequence are repeated) so to force the extremes to interpolate the first point and the last one. For some particular features it is not necessary to pre-select any entities. For example, to draw spline curves or straight line it needs only push the button 0 of the flystick and moving (fig.5). When necessary it is possible to constraint drawing of a curve or line in a specified plane, keeping constant one of its x,y,z, coordinates.

Figure 6 – On the left: creation of an extruded surface; on the right: creation of a revolved surface

Two kind of extruded surfaces are available in CAMVIRE: the freely extruded surfaces (fig. 6) and the predetermined extruded surfaces. The first needs only a profile to extrude along a path sketched in real time by the user. To create the second kind of extrusion surface it needs as inputs a profile and a predetermined path along which to extrude it. In this case, unlike the freely extruded surface, it is possible to extrude a profile along a straight line. Other available features for free-form modelling are the revolved (fig. 6) and the loft surfaces.

Unlike one-dimensional geometries (curves), to create surfaces it needs to select one or more curves as input. For example to model a freely extruded surface only one curve is necessary to use as profile to extrude, instead, to create a loft surface at least two curves are necessary as input data.

3.2 Other tools

To help user in drawing entities in connection with other ones, a 3D snapping tool has been implemented. When the pointing device is in proximity to the extreme of an existing geometry, user can decide to link the first or the last control point of the curves or surface he is drawing to the existing entity. This tool turns out very useful in connecting a profile and a path of an extruded surface or for the creation of multi-connected curve profiles.

CAMVIRE allows the designer to delete a single entity or to clean all the scene.

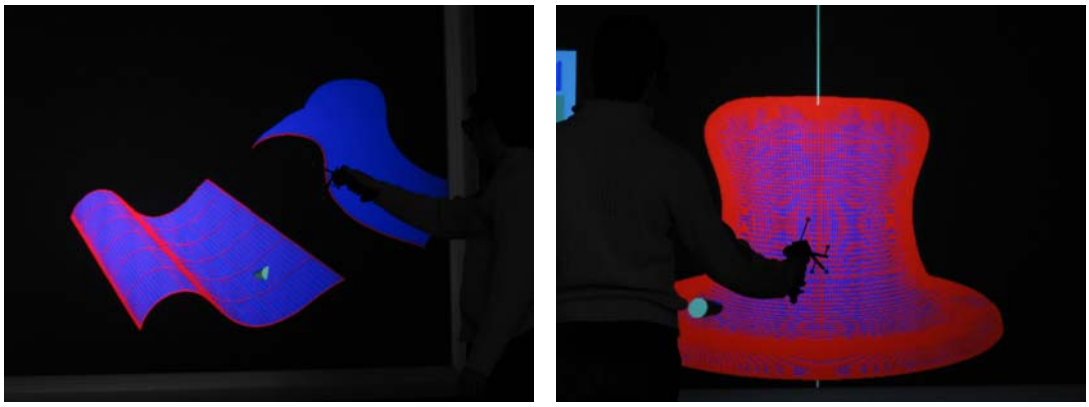

Figure 7 - Selection and highlighting of surfaces

The selection of an object is very simplified by using a ray picking algorithm; user must only positioning the wand in proximity to the geometry to select and push the button of the flystick. Selection of the object is highlighted by a color and/or appearance change of the entity (fig. 7).

To allow the designer interactively modify his models, a tool to manipulate the control points of curves and surfaces was also implemented. In the 3D menu a button, called *manip*, starts up the modification mode.

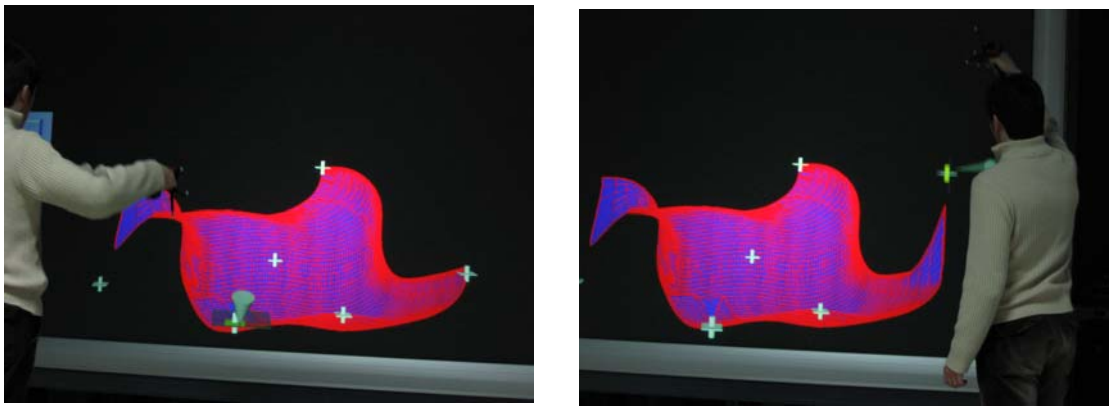

Fig. 8 – Modification of surfaces by dragging manipulators

In this case the user, by simply clicking near the object he wants to change, can add one o more *manipulators* that are connected to the control points which in that time are nearest the wand. Manipulators are object composed of a cylinder and a plane, selecting the former only one-dimensional translations (along cylinder axes) are allowed, instead, selecting the latter only two-dimensional movements (on the plane of the manipulator) are possible. It is also possible to rotate a manipulator of 90° degrees to allow displacements along any of the three orthogonal axes. Manipulators drag the control point which are connected to; when user wants to change the shape of any geometric entity in the scene he can, simply, pick on a manipulator and move it in any spatial position (fig. 8). After changing the shape of an object it is possible to delete the unnecessary manipulators.

4 Conclusions and future works

This paper shows the first steps towards a fully-integrated computer aided design system in virtual reality environment called CAMVIRE. The presented system, besides the stereoscopic visualization of the models, allows to create interactively in real time free-form curves and surfaces in the threedimensional workspace. Moreover by taking advantage of the 3D input device (flystick) user is free to use his arm to create any geometric entities in the space without the typical limit of the bidimensional input devices of the classical CAD software. Unlike of other previous works about integration of CAD potentialities in virtual reality systems [4-5-6], CAMVIRE presents two main advantages: thanks to the large screen display it is possible to see three-dimensional models in their real dimensions; moreover the use of the flystick allows user movements in a really free way, so to enhance the interaction with the system and to make it as real as possible.

Of course CAMVIRE, in view of further developments, represents a very powerful methodology in the field of industrial CAD modelling. In fact, one of the major requirements in this field is to speed up the transfer from the designer conceptual shape to a virtual CAD prototype to use for testing and evaluating. Without any doubt a system like CAMVIRE can make this tranfer more quick and can, globally, reduce the time-to-market and the costs-to-market of a product.

Many works are being developed to enrich and improve the presented system. Besides the enlargement of geometric tools, CAD data exchanging among CAMVIRE and other software application must be studied. It could very interesting, in fact, to study and modify an existing CAD model, made by an external software, in an immersive environment using CAMVIRE; on the other hands it could be necessary to export a model made with CAMVIRE to test it by a numerical analysis software. Problems related to importing and exporting of CAD models in Open Inventor-based system (like CAMVIRE) and interfacing with numerical analysis software were yet studied in some of our previous works [15-16-17].

Also the integration of numerical analysis codes in CAMVIRE should be a valid proposal of research activity. Many authors, in fact, have dealt with the integration of finite element method codes in virtual reality system [18-19-20-21].

Other interesting studies could be the different ways of interaction with the system, by using additional tracked input devices [22-23] and/or by a multimodal approach, with speech recognition commands [8].

Bibliography

[1] C. Hummels, G. Serts, K. Overbeeke, "An intuitive two handed gestural interface for computer supported product design", proceedings of International Gesture Workshop, Bielefeld, Germany, September 1997

[2] L. Cutler, B. Frolich, P.Hanrahan, "Two handed direct manipulation on the responsive workbench", proceedings of Symposium on Interactive 3D Graphics, 1997

[3] Liu X., Dodds G., McCartney J., Hind B., "Virtual Design Works –designing 3D CAD models via haptic interaction", Computer-Aided-Design , vol. 36, p.1129-1140, 2004

[4] Cohen J.M., Markosian L., Zeleznik R.C., Hughes J.H., and Barzel R.: "An Interface for Sketching 3D Curves", Proceedings of 1999 Symposium on Interactive 3D Graphics, ACM SIGGRAPH, 1999.

[5] Butterworth J., Davidson A., Hench S., Olano T. M.: 3DM: "A Three Dimensional Modeler Using a Head-Mounted Display", Proc. 1992 Symposium on Interactive 3D Graphics, Cambridge, Massachusetts, p. 135 - 138, March 29 - April 1 1992.

[6] Usoh M., Slater M., Vassilev T.: "Collaborative geometric modelling in immersive virtual environments", Eurographics Workshop, 1995.

[7] Liang, J., Green M.: JDCAD: "A Highly Interactive 3D Modeling System", 3rd International Conference on CAD and Computer Graphics, Beijing, China, p. 217-222, Aug. 1993.

[8] Dani T. H, Gadh R.: COVIRDS: "A Conceptual Virtual Design System", Computer Aided Design, Vol. 29(8):555-563, 1997.

[9] Chu P. , Dani T. H, Gadh, "Multi-sensory user-interface for a virtual reality based computer aided design system" , Computer Aidede Design , vol. 29 , No. 10, p. 709-725, 1997.

[10] Open Inventor User's Guide from Mercury – www.tgs.com

[11] Open CASCADE web site www.opencascade.org

[12] OpenGL Reference Manual: The Official Reference Document to OpenGL, Version 1.2 (3rd Edition) by Dave Shreiner

[13] Wernecke J., "The inventor mentor: Programming object-oriented 3d graphics with open inventor", Release 2, Addison Wesley, September 2001

[14] Becker M., Gola P., "Rhino NURBS 3D Modelling" , ISBN: 0735709254, Ed. Textbook Binding, August 1999

[15] F.Cappello, R. De Amicis, T.Ingrassia, A.Mancuso, V.Nigrelli, “Finite element re-analysis in virtual reality environments”, Proceedings of Virtual Concept 2005, Biarritz, France, November 8th – November 10th, 2005

[16] F.Cappello, R. De Amicis, T.Ingrassia, A.Mancuso, V.Nigrelli, “A tool for the interactive mesh refinement in virtual environments”, Proceedings of Virtual Concept 2005, Biarritz, France, November 8th – November 10th, 2005

[17] F.Cappello, R. De Amicis, T.Ingrassia, A.Mancuso, V.Nigrelli, “Un nuovo strumento per lo studio dei risultati di analisi FEM”, XVII International Conference Ingegraf-ADM, Siviglia, Spagna – Giugno 2005

[18] Lu L., Connell M., Tullberg O., “ First step towards applying VR in interactive finite element analysis”, Report 01:7, Department of Structural Mechanics, Chalmers University of Technology, Göteborg, Sweden, 2001

[19] Liverani A., Kuester F., Hamann B., “Towards interactive finite element analysis of shell structures in virtual reality“, Proceedings of IEEE Information Visualization, July 1999, pp 340-346

[20] Lee K., Price M., Armstrong C., “ViSiCADE a Virtual simulation environment for seamless integration of CAD/CAE into VR ”, ISSC conference, Belfast, june 2004

[21] Connell M., Tullberg O., Lu L., “The use of Virtual Reality in Interactive Finite Element Analysis by Java3D API”, Applied Virtual Reality in Engineering and Construction, proceedings of the conference AVR II and CONVR, pp 60-68, 2001

[22] De Amicis R., Fiorentino M., Stork A., “Parametric Interaction for CAD application in Virtual Reality Environment”, XII ADM International Conference, Vol. D3, pp. 43-52, 4-7 September, Rimini, Italy, 2001

[23] L.M. Encarnacao, A.Stork, O.Bimber, D. Schmalstieg, J.Barton, “The virtual table – A future CAD workspace”, SME Computer Technology Solutions Conference, Sep. 13-16, 1999, Detroit