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VIRTUSCADE – A FEM PREPROCESSOR TOOL BASE ON PARAMETRIC SURFACES

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Abstract. The knowledge of latest technology that allows the development of competitive products in reduced times is crucial to guarantee a sustainable growth of the national industry. This work presents the development of a computational system for the Virtual Design of products, the VirtusCADE, which is a CAD/CAE interactive software (Computer Aided Design/Computer Aided Engineering). The VirtusCADE includes 3D geometric modeling of surfaces and solids and mesh generation. The system uses the parametric modeling of surfaces, including algorithms for determination of intersection between surfaces and for triangular mesh generation in trimmed parametric surfaces. The graphical interface is interactive and allows the direct real time manipulation of objects (lines, surfaces and solids) in 3D using the OpenGL technology. The system prioritizes the usability, implementing several graphic tools that facilitate the manipulation in 3D. The VirtusCADE contemplates the structural simulation through the Finite Element Method. The code architecture is based on oriented object programming, which allows great scaling capability for the implementation of new tools. This project has great applicability in numerical simulation of physical phenomena, such structural analysis of buildings, vehicles parts, with impact in the industries of civil construction, metal-mechanics, aerospatial, naval and automotive.

1 INTRODUCTION

The modern industrial design can no longer ignore the techniques of computer simulation, to the conception, representation and simulation of components and products. The automotive, shipbuilding, aerospace and metal-mechanics are examples of industries that use computer simulation in all stages of the design process. Among the various types, the structural simulation assumes a major importance, as the structural features are directly related to the feasibility, safety and durability of the product. Structural simulations are usually done with computer codes based on Finite Element Method (Zienkiewicz e Taylor, 2005), which use virtual models with the geometric data of the part, the physical properties of the materials used and the boundary conditions and loads to which the part is submitted.

The commercial softwares have a high license cost, maintenance and, in most cases, they have a closed architecture, what makes it difficult or impossible to use for scientific research where it is necessary the generation or publication of data not available in the software package.

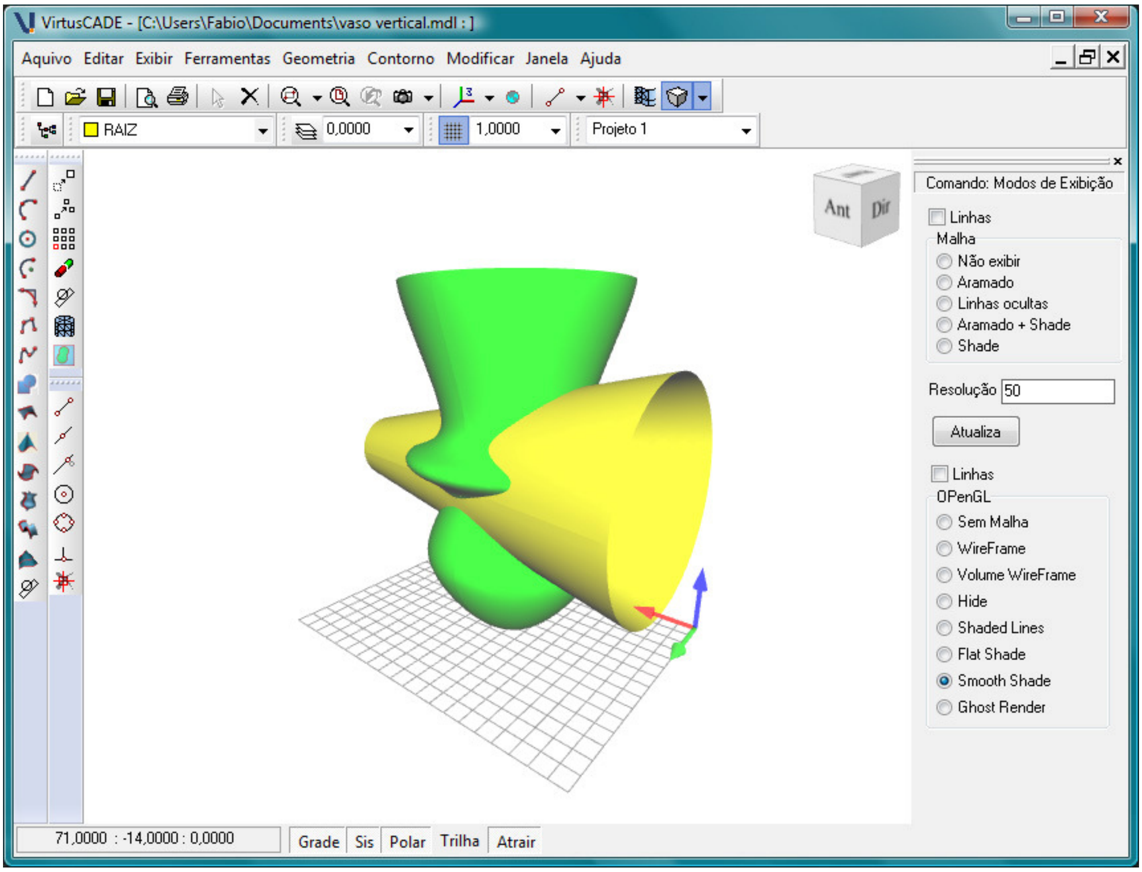

Figure 1: VirtusCADE interface with two parametric surfaces.

Some packages allow some kind of customization, but do not provide access to its core so that the really important changes can be made. It is in this context that this work is inserted. The VirtusCADE is a computer system for the virtual development of products, which has been created from the simulation software T-CADE (Teixeira, 2003). The VirtusCADE is an interactive system with features of direct manipulation of objects, capable of creating objects from parametric surfaces and complex Boolean operations from the intersection of geometric objects.

2 PARAMETRIC REPRESENTATION OF CURVES AND SURFACES

Parametric representations are a robust way for the computational representation of geometric objects like curves and surfaces.

The use of parametric representations is an important tool in three-dimensional geometric modeling to analyze design problems of engineering, combining geometric precision, with endless possibilities of geometry, to a great simplicity of implementation and computational manipulation.

The VirtusCADE uses representations of parametric surfaces of quad domains that are used to generate geometric models for analysis or simulation of design problems of engineering. The implemented surfaces are of the following types: Planes, Bilinear, Ruled, Revolution, Coons, Loft and Sweep. These surfaces always use parametric curves in its definition and also for the definition of cutting curves.

Thus, the modeling begins with the creation of curves that will lead to a surface. For example, for the generation of a revolution surface it is necessary to have first created the profile curve and the axis (see Figure 1).

3 INTERSECTION OF SURFACES

The determination of intersections between surfaces is one of the most important topics of computer graphics. There are several examples of applications where it is necessary to determine the intersection curves between two surfaces, which can be highlighted: geometric modeling to generate finite element meshes in shells and solid, B-Rep representation from CSG, determination of profiles surfaces, Boolean operations, construction of blending surfaces between two surfaces, determination of tools tracking (CAM), detection of interference and collisions.

All these applications are present in a greater or lesser degree in systems for engineering design and simulation (CAD/CAE).

The techniques for determining the intersection curves btween surfaces are particularly important in product design, as they allow the modeling of complex geometries cutting surfaces by their intersection lines. The intersection method proposed (Teixeira e Creus, 2008) and implemented in VirtusCADE uses adaptive subdivision according to the local curvature of surfaces and is based on the divide-and-conquer principle (Hougton *et al*., 1985). The surfaces are subdivided into successive steps until there are no sections with curvature greater than a certain limit. This way, it is possible to reduce the intersection problem, locally, to the case of the intersection between two planes.

The great advantage of this method is that it is completely independent from the type and shape of the surfaces, as well as the shape and complexity of the intersecting curves. These factors are important to ensure the robustness and generality of the method, some of the core characteristics of CAGD (Computer Aided Geometric Design).

The intersection process is done in four steps: adaptive subdivision, intersection between sections, refining the results and parametrization of intersecting curves. The intersection curves are determined with high accuracy level, with maximum error of 10^{-12} related to the maximum dimension involved.

The resulting intersection curves are mapped on the parametric space of each surface and can be used to create cuts and subdomains to the mesh generation (see Figure 2).The first page must contain the Title, Author(s), Affiliation(s), Keywords and the Abstract. The second page must begin with the Introduction. The first line of the title is located 3cm from the top of the printing box.

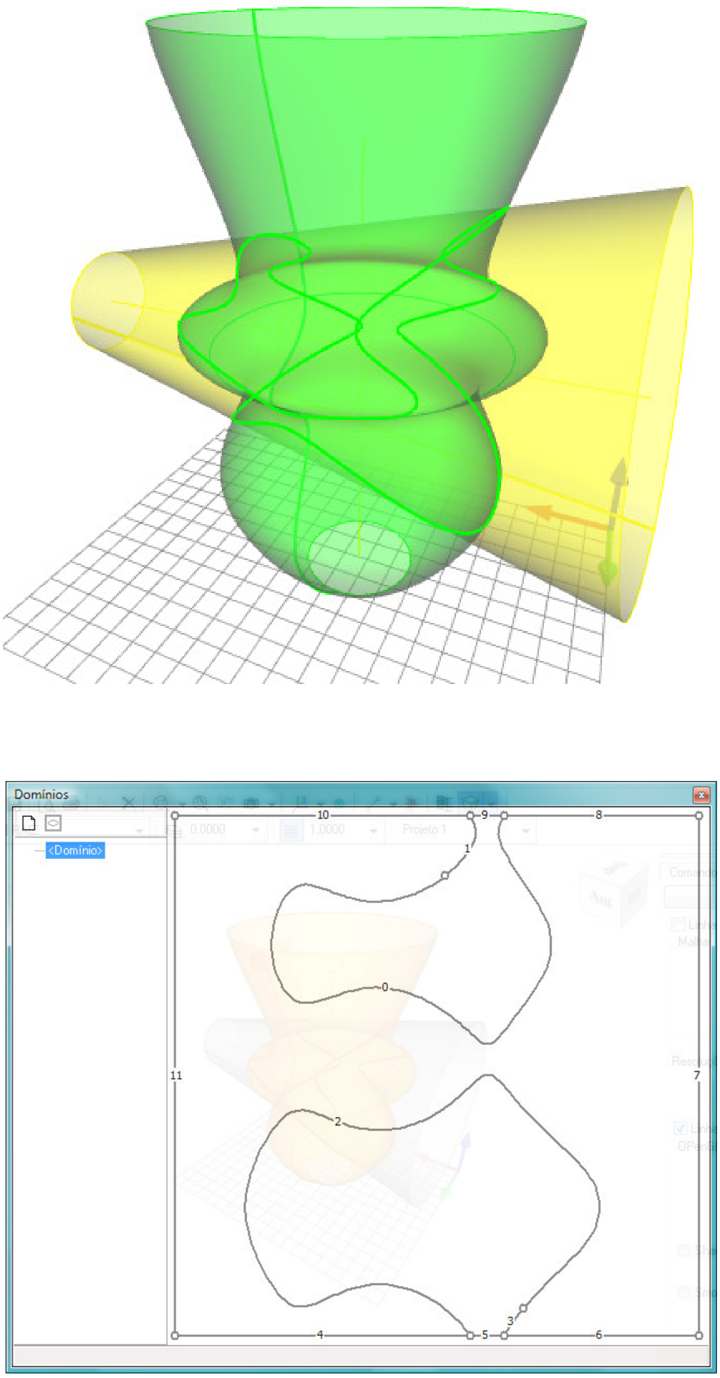

Figure 2: Surface intersection and subdomains on parametric space.

4 MESH GENERATION

The algorithm implemented in VirtusCADE is an advancing front type and uses a background mesh, constructed by recursive subdivision to regulate the size of the elements depending on the local curvature of the different regions of the surface (Teixeira e Creus, 2003). The choice of a advancing front type method is mainly due to the characteristic of this type of method that allow the construction of meshes in domains with arbitrary boundaries, such as those that occur after the determination of intersection curves between two surfaces. The algorithm uses angular tolerances applied to the normal vectors of the curves and the surface, in order to take into account the local curvature in both the discretization of the contour, as in the generation of background mesh. The algorithm has the ability to create quality mesh in trimmed domains, with holes and internal curves. The meshes generated are sensitive to the curvature of the surfaces and contours of the subdomains.

One can generate meshes in more than one subdomain on each surface, which increases the generation potential of the program. The quality of all meshes presented in the examples is excellent, with average $\alpha \geq 0{,}95$ in all cases (see Figure 3).

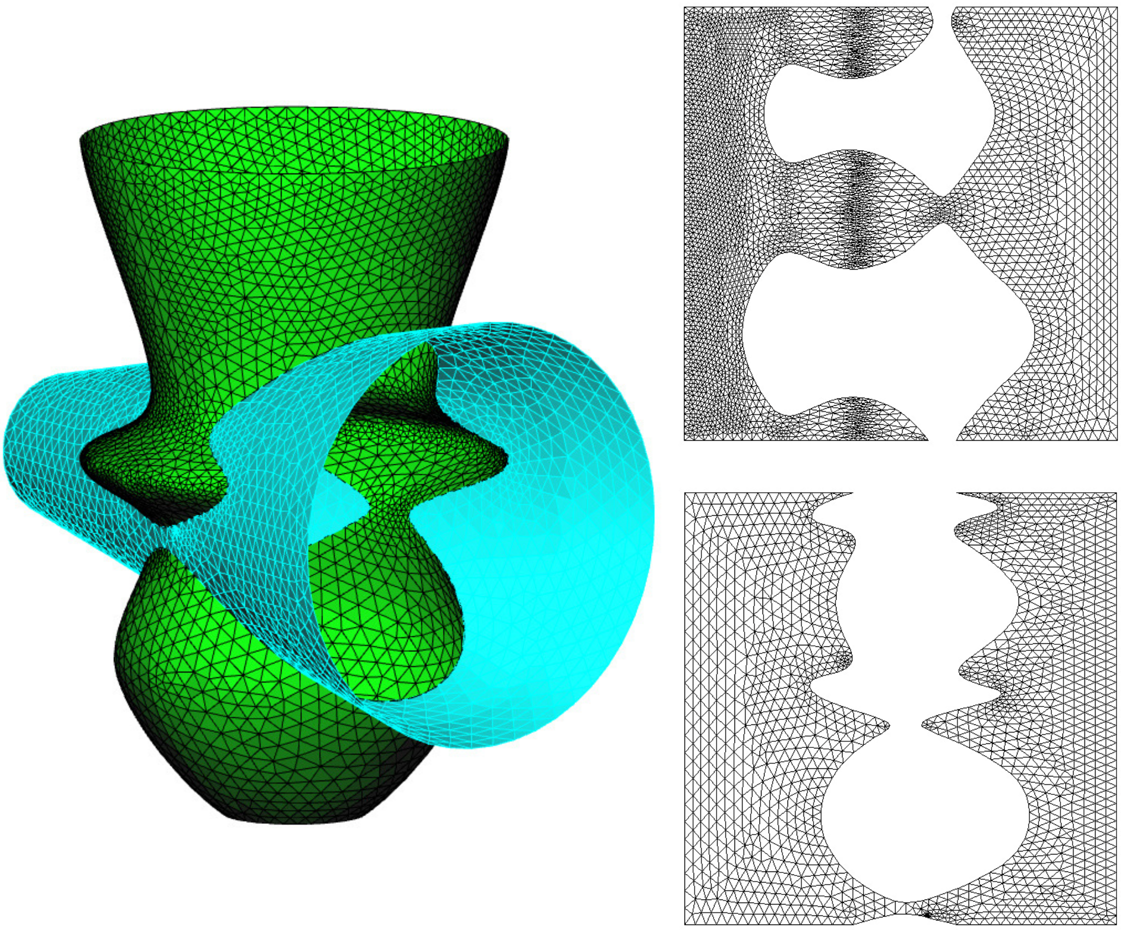

Figure 3: Mesh on two trimmed surfaces using subdomains.

5 ASSIGNMENT OF PROPERTIES, LINKS AND LOADS

The assignment of material, properties, links and loads is made directly on the geometric model based on parametric surfaces. Thus, when generating the mesh, the elements inherit the attributes of the source surface. Properties can be the materials with their physical constants and geometric properties, such as thickness or the section of a bar element.

The properties related to materials and geometries are encapsulated in an abstract property that divides the objects (surfaces) into categories and is called the Object Class. That way, surfaces of the same class have the same properties. Surfaces belonging to different classes have different properties.

The classes are meant, in addition to organizing the assignment of properties, to arrange the models in a hierarchical manner, as can be classes derived from other classes in an almost unlimited number of levels.

The assignment of boundary conditions and loads follows a procedure similar to that used in the assignment of classes of properties. At first, it is necessary to define categories of links and loads. After that, one can then assign these categories directly to surfaces, curves and points of surfaces.

When the mesh is generated, the nodes and elements belonging to regions with links and loads inherit these attributes from the surface on which they were generated.

6 FEATURES OF THE GRAPHIC INTERFACE

The VistusCADE uses a 3D interface based on OpenGL providing high performance with quality rendering in real time. Thus, it guaranteed an average of 40 FPS (frames per second) on computers with dedicated graphics card. Several tools were implemented to support interactive design and modeling, including real-time feedback and tools sets for geometric support, as well as tools that focus on usability.

An important tool created is the QuadMenu (see Figure 4), which performs the camera control from the movements of the cursor over a circular menu, where the commands are arranged in quadrants, facilitating the selection of commands and its memorization.

Its operation is based on the mouse gestures interaction (Zeleznik e Forsberg,1999), but with a twist: The selection takes place, not through pre-defined gestures, but the direction of motion and distance traveled by the cursor.

Figure 4: QuadMenu: The camera movement command is driven in a single motion.

The camera can also be controlled from one version of the Viewcube (Khan et al., 2008), This tool allows the changing of pre-defined views in a simple and intuitive way avoiding disorientation, common in abstract 3D environments (see Figure 5). From a cube in the upper right corner of the screen with the name of the views on the faces, the user has the control and indication of the orientation of the scene.

When used as a controller of the position angle of the observer, by clicking on the faces, edges or corners of the cube, the cube and the scene change its orientation adjusting themselves to the corresponding view.

When the scene is modified by other moving methods of the camera, the cube adjust itself to indicate the new orientation. The transition between the views changes is done using animation (motion frames) to soften the change and avoid the disorientation of the user caused by sudden changes of scene.

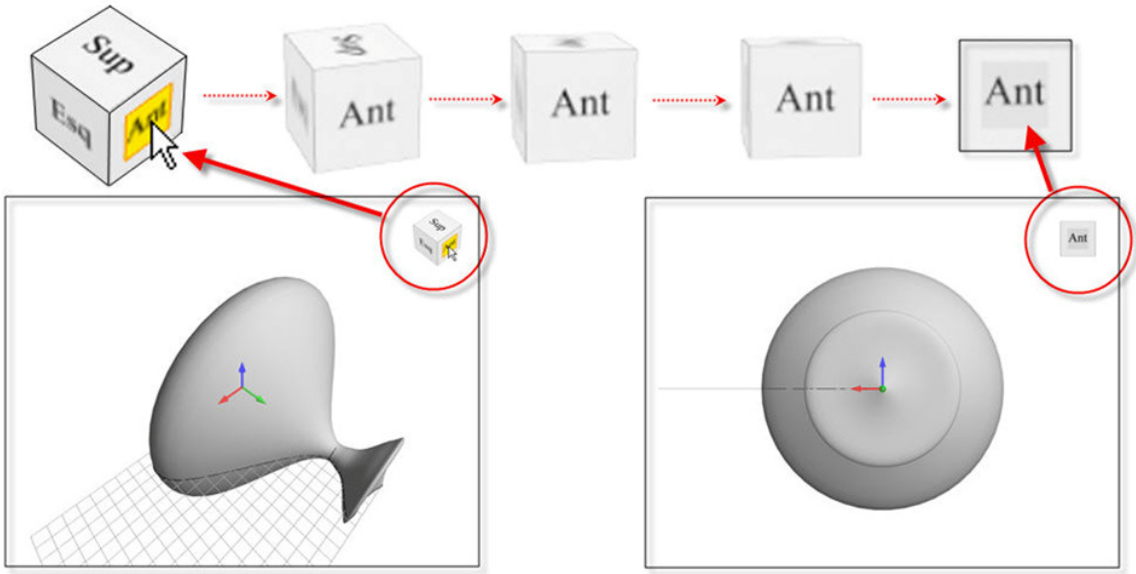

Figure 5: ViewCube: Clicking on the front surface of the cube, the cube and the scene adjust themselves to the new 3D view.

7 FINAL CONSIDERATIONS

The VirtusCADE is a system for virtual product design that includes a modeler and mesh generator capable of generating complex models from cuttings of parametric surfaces with different geometries. The program allows you to generate data for analysis by finite element codes directly on the geometry, independent of the mesh.

The program was developed as a platform for research and development both in the area of geometric modeling, and for the development of codes of analysis and post-processing.

In the next stages, will be implemented the integration of VirtusCADE data structure with the online system Virtus, a tool currently in development for the design of products that includes all stages of the process.

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