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A NEW TOOL FOR IMMERSIVE 3D FREE-FORM SURFACE MODELLING AND REFINING

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1. Introduction

Currently, the task of modelling and refining 3D free-from surfaces is usually carried out by using traditional 2D interfaces. To do so, most commercial modelling software (e.g. Maya, AutoCAD, Rhinoceros, Autodesk Inventor) provide the user with pseudo-3D visual information in a 2D visual interface: different windows displayed in a standard personal computer monitor show different orthogonal projection views of the 3D model or isometric projection views. To modify the 3D model, the user must select one element in one of the windows and modify its attributes either by using the mouse or the keyboard. Whilst this technique might be adequate for traditional 2D drawings, like technical drawing, it is not for the modelling of 3D free-form surfaces.

Modelling and refining of 3D free-form surfaces by means of 2D interfaces has a main drawback: the user is forced to work in an unnatural environment. As the computational 3D model is decomposed in orthogonal projection views, every 3D modification must be thought as decomposed in these planes. Thus, fully 3D interaction is non-existent as the user cannot refine directly the surface like in a real world setting (using, for example, clay models). This human-computer interaction problem increases the complexity of the creative process that should focus on the 3D model form evolution rather than in the limitations of the interface. As a result, the whole design process takes longer than if it was carried out in a truly 3D environment.

There have been several attempts to solve this human-computer interaction problem to facilitate the modelling and refining of 3D free-form surfaces. In increasing order of functionality, they can be classified as a) 3D visualization systems with 2D interfaces for modelling or refining, b**)** 2D visualization systems with 3D modelling or refining interfaces, c) 3D visualization/modelling systems d) 3D visualization/modelling/refining systems. Systems in the last category are the most useful to the design process but also the most challenging to implement. In fact, currently there are no commercially available systems that provide the 3 functionalities (3D visualization/modelling/ refining) with advanced features.

Systems in the first category only provide full 3D visualization of a model built in a traditional environment (i.e. using 2D interfaces). The software Maya is an example of this type of system: 3D models are built and modified by working on the orthogonal and isometric projection views. Modelling and refining tasks are carried out using the keyboard and the mouse as 2D interfaces. However, 3D visualization of one isometric view is provided by using stereoscopic vision (with shutter or polarization glasses). This 3D visualization facilitates the evaluation of the changes made to the geometry, but these changes still must be made using the projection planes. Other systems in this category can be found in [Mine 1997], [Astheimer 1995], [Fadel 1995].

Systems in the second category provide 3D interfaces for modelling or refining but not 3D visualization. The prototypes described in [Fiorentino 2010], [Liu 2005] are examples of this approach, where a phantom device is utilized to refine a 3D model displayed in a 2D monitor. Other example can be found in [Qin 2005].

A further improvement is represented by systems that, besides providing 3D visualization, also allow for 3D modelling. In this case the 3D model can be built and visualized using 3D interfaces. However, the process of refining is still performed by using 2D interfaces. Examples of this type of system are [Stark 2010].

Finally, the most advanced systems belong to the fourth category: full 3D visualization, modelling and refining. The commercial product Leonar3Do allows 3D visualization by using stereoscopic vision and 3D modelling by construction of primitive forms by using a 6 degree of freedom device (airborne). The airborne is also used for 3D refining by selecting a point in the polygonal mesh and moving it as desired. The main drawback of Leonar3Do is the representation of 3D free-forms using a polygonal mesh, instead of NURBS, which hamper smooth modification of forms. Regarding research prototypes, [Bourdot 2010] presents one of the most complete systems reported in the literature. It consists of a multimodal virtual reality-based system where the 3D visualization is achieved by using a CAVE-like stereoscopic retro-projection platform. 3D modelling and refining is performed by using a 6 degree of freedom device as well as voice and gesture recognition systems. The main two drawbacks of this system are the lack of interaction with the real environment and that the system is not yet integrated to a commercial CAD system.

In this paper we present a new tool that provides 3D visualization, 3D modelling and 3D refining of free-form surfaces. For 3D visualization, stereoscopic vision is used on a commercial CAD system environment. For 3D modelling and refining, the system receives the input from a 6 degree of freedom device (airborne). Unlike previous proposals, the integration of these features results in allowing the direct 3D manipulation of free-form surfaces by using a commercial CAD system interface. Thus, its inclusion in industrial production processes should be smoother than that of solutions that do not interact with current CAD systems.

2. Proposal

To solve the described human-computer interaction problem when modelling and refining free form surfaces, we propose a new interactive system. The system uses stereoscopic viewing, 3D curves and surface editing functionalities and fully interactive 3D input. To accomplish this, the system takes the advantages of two commercial products: Autodesk Maya and Leonar3Do Virtual Reality Kit. Autodesk Maya is a CAD package able to build and edit 3D freeform-based geometries and display them using stereoscopic vision. Leonar3Do provides a 6 degree-of-freedom device (airborne) for 3D modelling. The hardware layout is shown in figure 1.

The developed system is based on a plug-in programmed for Maya that allows connecting both commercial products (Maya and Leonar3Do). As a result, the airborne of Leonar3Do can be used as a 3D input for modelling and refining the 3D model, which is visualized in a 3D manner thanks to the stereoscopic vision provided by Maya.

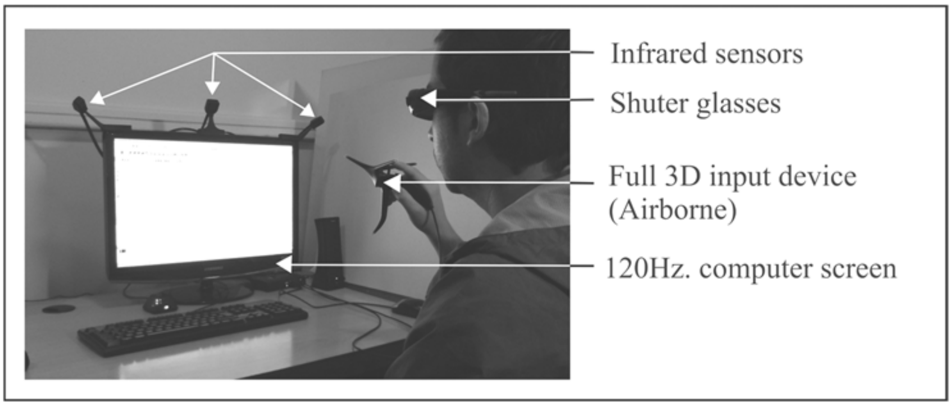

Figure 1. The hardware layout used to implement the prototype

In the context of this first development, the plug-in has been implemented with the following five functionalities:

- **Recognition of the airborne position in the working space of Maya**. Leonar3Do identifies the position of the airborne in its working space by means of 3 infrared sensors located in a row at the top of the display, as shown in Figure 1. The information of the 3D coordinate (x,y,z) is then sent to Maya. In the working space of Maya, a pointer appears in a position close to that of the airborne. This pointer is called ***space locator***. This functionality operates even when a change on the point of view of Maya space occurs.
- **Allowing the selection of curves or surfaces in Maya** by pressing a button of the airborne when the space locator in Maya is close to a given curve/surface. The curve/surface at the shortest Euclidean distance to the space locator is selected.
- **Allowing the selection of a control point in a curve/surface in Maya** by pressing a button of the airborne when the space locator in Maya is close to a given control point (in an already selected curve/surface). The control point at the shortest Euclidean distance to the space locator is selected.
- **Allowing the modification of the curve/surface** by freely moving the airborne once a control point has been selected. In this case, periodic information about the 3D position of the airborne is sent to Maya to update the 3D position of the control point and thus, the form of the corresponding NURBS.
- **Creation of new curves in Maya** by pressing a button of the airborne in the 3D position selected as the origin of the curve, moving the airborne freely in the 3D space while keeping the airborne button pressed.

Thus, these functionalities allow the user to interact with Maya using the airborne. The normal functionalities of Maya (as lofting, deleting, extruding, etc.) remain available as usual.

Figure 2 shows an example of the steps carried out by a user of this new system to model and refine a freeform surface. First, the user builds several curves in the 3D working space of Maya aided by the airborne (Step 1). The user can change the view point of the cameras in Maya (two cameras which provide the stereo vision) to perform visual inspection of the curves from different points of view (Step 2). If the user decides to modify any curve, at any moment s/he can select and modify it by selecting and freely moving control points on the curve using the airborne (Step 3). Once the set of curves is deemed appropriate, the user selects them all and executes the command *loft* of Maya to build a surface (Step 4). Analogously to the case of the curves, when the new surface is displayed, the user can carry out a visual inspection (Step 5), select any surface control point and freely move it in the 3D space (Step 6).

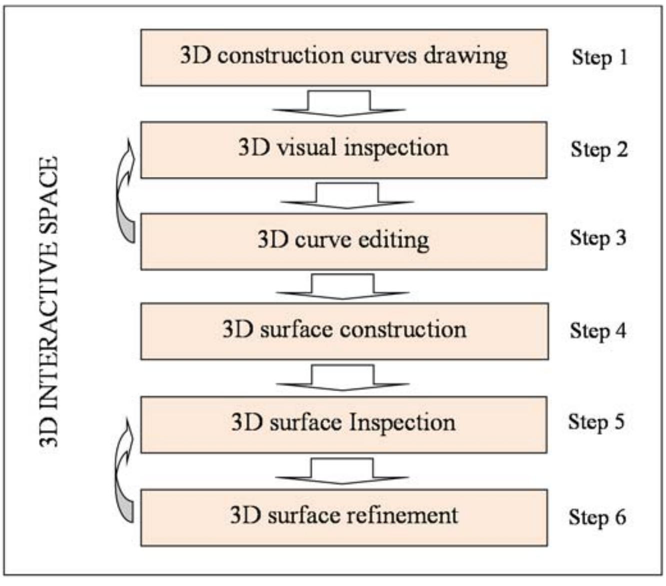

Figure 2. The proposed surface modelling and refinement method

2.1 Leonar3Do-to-Maya plug-in technical details

The proposed plug-in must be executed from the Maya environment. Once executed, the plug-in works as an independent cyclic thread.

The general plug-in execution schema is depicted in Figure 3. This schema can be subdivided in two types of steps: **invariant** execution steps (upper part of Figure 3)**,** which are in permanent execution; and **selection** steps (lower part of figure 3), whose execution depends on the selection/creation/edition of a curve/surface. The plug-in starts by executing the 4 invariant steps. Then, according to the user interaction with the airborne buttons and the existing objects, the plug-in executes the selection steps. Next, the cycle restarts by executing the invariant steps.

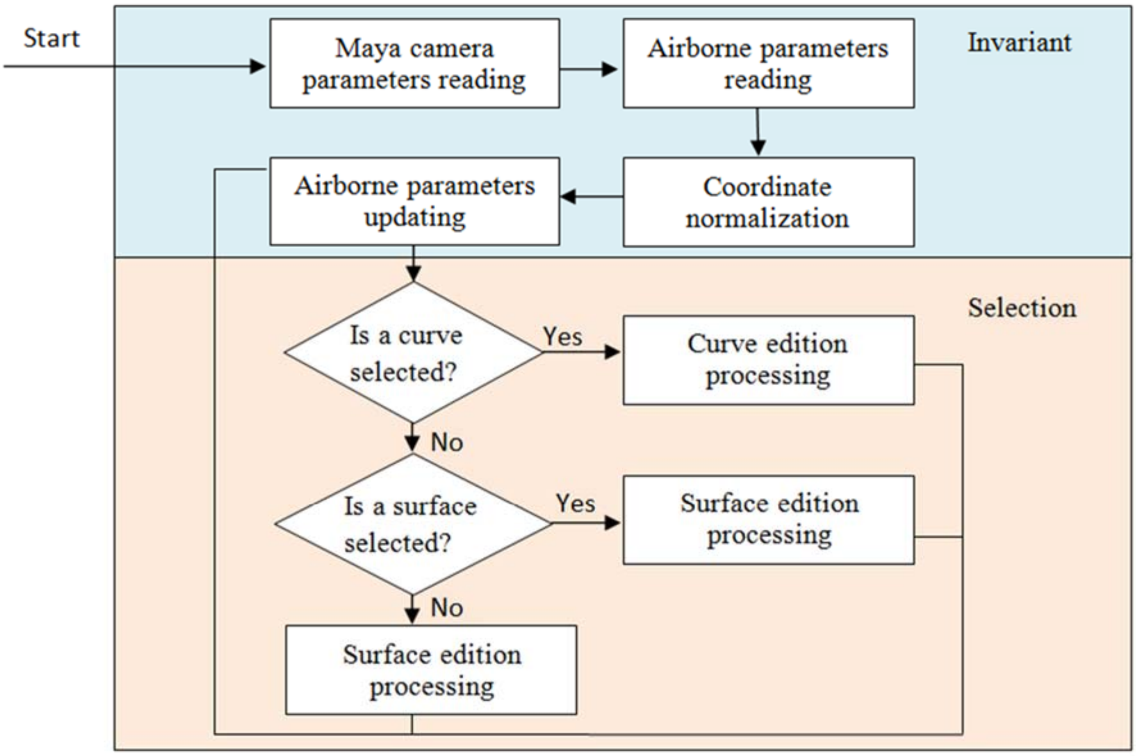

Figure 3. Flow diagram of the proposed plug-in

The invariant execution steps start with the extraction of perspective translation and rotation parameters of the camera view of Maya world. Next, the current airborne position and rotation in the Leonar3Do referential space are extracted. Then, the information of the airborne position is translated into the corresponding position in Maya world in order to properly update the airborne position when visualized. The invariant steps end with the updating of the position of the airborne in Maya world.

The third invariant step is required since Maya and Leonar3Do coordinate spaces are not directly related, but independent. A proper perspective transform is then needed in order to find the correspondence between the coordinate systems of both worlds. The following considerations are stated for this transform:

- The coordinate system from Leonar3Do can be represented as a parallelepiped inside the Maya space.
- The coordinate system from Maya is considered static. Then, any variation in the spatial relation between Leonar3Do and Maya spaces will be considered as a variation in Leonar3Do space.
- The origin of the Cartesian axes in both spaces is the same.

These considerations are graphically represented in Figure 4. As the user may want to inspect the objects from different views, a transform between both coordinate systems must consider the possibility of rotations. As a simplification associated with the way the Maya world can be traditionally rotated (2 degrees of freedom constraint, using the mouse or keyboard), the rotation angle around the z axis is set to 0, leading to the following transform:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\beta & \sin\alpha\sin\beta & \cos\alpha\sin\beta \\ 0 & \cos\alpha & -\sin\alpha \\ -\sin\beta & \sin\alpha\cos\beta & \cos\alpha\cos\beta \end{bmatrix} \times \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix}$$

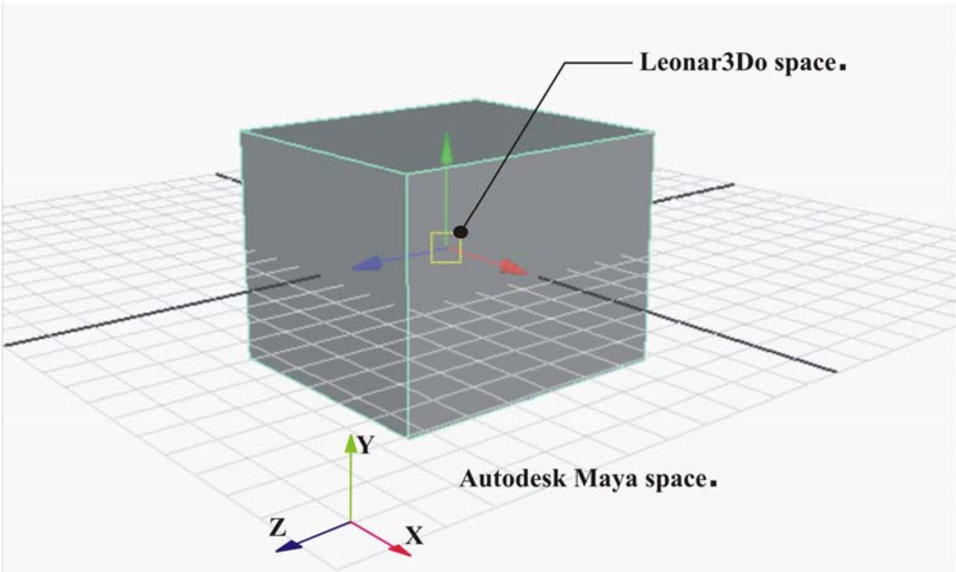

Figure 4. Graphical representation of the relation between Leonar3Do and Maya spaces

After the invariant steps are executed, the interaction of the airborne buttons with objects in Maya world is verified in order to determine the selected object. This verification includes analysing the proximity of the airborne to the control points of the objects to determine the right elements of interaction. These functionalities allow the creation of curves and the edition of control points from existing curves and surfaces. Finally, the process will start a new iteration.

3. Prototype implementation

The prototype system was implemented by using the following hardware and software:

Hardware	Software
• CPU Intel core i7, 2.93 GHz. • Graphic Card NVidia Quadro FX 4800. • Leonar3Do Virtual Reality Kit (Six degree airborne). • NVidia 3D viewing Kit. • 120 Hz. Computer screen.	• Autodesk Maya. • Visual C++ 2008. • Leonar3Do API. • Autodesk Maya SDK.

The developed plug-in linking the Leona3Do Virtual Reality Kit, NVidia 3D vision (stereoscopic glasses and glass signal emitter) and Autodesk Maya, has been developed by using C++, Leonar3Do API and Autodesk Maya SDK.

Figure 5 shows an example of the results obtained using the developed prototype to apply the procedure described in Fig. 2. Fig.5a shows the creation of three 3D curves, which are then modified as shown in Fig.5b. The stereoscopic view of the 3 curves is shown in Fig. 5c. By applying the *loft* command to the 3D curves, a 3D surface is created as shown in Fig 5d. This surface can also be modified, as shown in Fig. 5e. The isometric view of the modified 3D surface is shown in Fig. 5f.

Note that because the system is based in the modelling capabilities of Autodesk Maya, any object previously modelled by NURBS curves/surfaces in Maya, can also be refined or modified by using the presented system. The figure 6a shows an example which was originally modelled in Rhinoceros software and then transferred into Autodesk Maya for refinements. Figure 6b and c show different views of the model once modified with the described prototype.

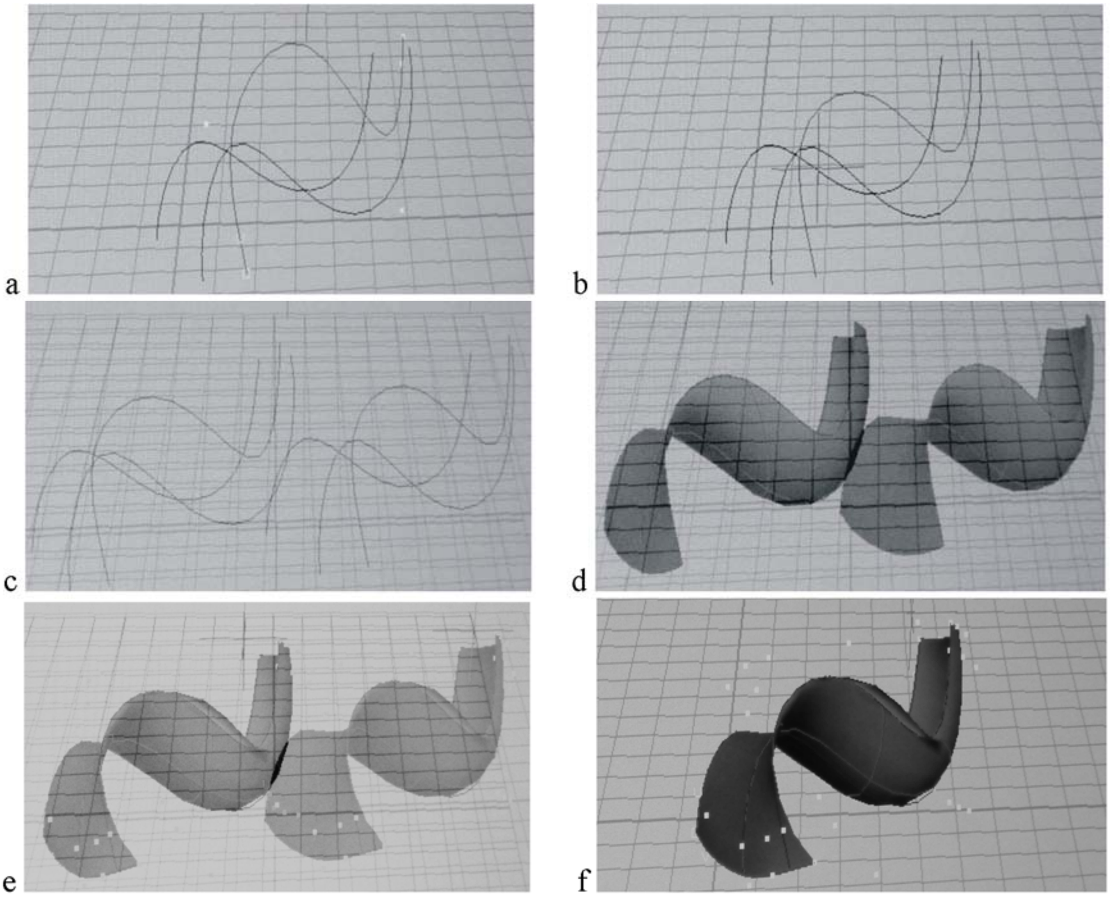

Figure 5. Example of a surface obtained by using the developed prototype

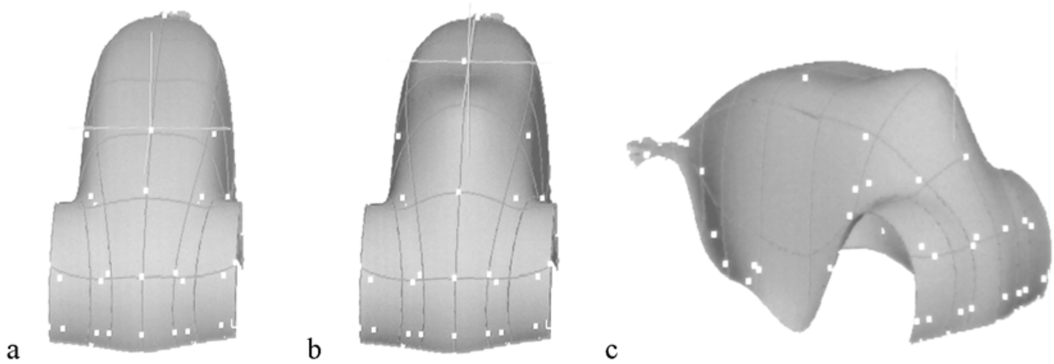

Figure 6. Example of a surface which was originally modelled in Rhinoceros software and then transferred into Autodesk Maya for refinements using the developed prototype

4. Summary and conclusions

In this paper a new tool for 3D visualization, modelling and refining of free-form surfaces was presented. The tool is based on a plug-in developed to exploit the advantages of two commercial products: Autodesk Maya and Leonar3Do Virtual Reality Kit. The stereoscopic visualization feature of 3D models of Maya and its 3D curve and surface editing functionalities are leveraged by the 3D input that can be delivered by using the 6 degree-of-freedom device provided by Leonar3Do Virtual Reality Kit. We have used this prototype system to model and modify freeform-based geometries,

either constructed in Maya or imported from another CAD package. As a result, the human-computer interaction becomes smoother, especially when refining the 3D model.
At this first implementation stage, we would like to highlight that the system is more suitable for 3D refinements than complete 3D geometric modelling. For example, free-form surfaces that contain some specific constraints (e.g. planar areas) were not possible to be built in a precise way from the lofting of 3D free curves. The reason for this lies in the lack of human precision when drawing 3D curves freely. Thus, additional steps must be carried out (e.g. point alignments) for exact surface construction. Further research should focus on improve this weakness, by allowing dual curve/plane modelling.

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