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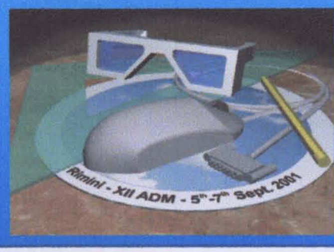

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Full-Scale Surface Modeling in Virtual Reality

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Abstract

This paper reports last developments and improvements of VISM (Virtual Integrated Surface Modeler) [1] running on I.R.R. [2] (Immersive Reconfigurable Room), installed at V-Lab (http://v-lab.ingfo.unibo.it) – University of Bologna – Forlì. VISM was originally developed for VRDD (Virtual Reality Design Desk) to explore a completely new concept of free-form surface modelling based on 3D tracking device and stereographic vision.

More in detail, the use of an intuitive and tracking based surface modeller in a Immersive Reconfigurable Room (similar to CAVE Automatic Virtual Environment) gives the designer a definitely major advantage compared to a workstation user: he doesn't need any chalk full-scale model. Normally a designer, wishing to create or modify a project, follows these steps:

- several hand-made colour sketches;
- chalk or clay models construction;
- 3D CAD modelling.

These 3 activities may be collapsed in a single generative session in Virtual Reality.

Furthermore VISM now includes a simple module to import a NURBS surface or group of surfaces in order to provide the designer a complete tool to create and modify a 3D geometry.

Many benefits have been detected using the modified version of VISM, not only in terms of intuitive and easy-to-use interface, but much more in terms of time saving and 3D shape feeling.

1. INTRODUCTION.

1.1. New ideas and product restyling.

The styling stage is a day by day growing part of the design process. Sometimes styling and engineering design use to follow completely separated ways, and also people involved in these activities have very different cultural backgrounds.

This lack of homogeneity many times leads to a big gap between styling, also influenced by commercial directives, and mechanical and industrial engineering.

Is there any way to collapse this gap, greatly compressing integration of design stages (styling and engineering) [11] and also time – to market, saving a huge amount of time?

An answer may be found in an original conceived software interface, joining Virtual Reality and full scale modeling.

That is VISM (Virtual Integrated Surface Modeling). More in detail, a design process may start from the need of modifying a product already on the market or from a brand new idea (or commercial request).

- **New product design:** drawing, painting, history are basic knowledge used by stylers to match a commercial request, personally interpreting shapes and colours. The most part of the designers prefers to produce hand-made sketches to be totally free from 3D modeling rules [10].
- **Existing product restyling:** this is a very frequent situation in the industrial area, since industrial engineers usually prefers to follow the evolution of the product instead of a complete redesign. Customer feedback, client assistance suggestions and market directives usually determines whether redesign or briefly restyle a product. But, most of times, product modifications are hugely less expensive then the development of a new product.

In both cases, when the best shape is found, the following step is to build a concrete clay o chulk model, starting from half-scale (or less) up to full scale models. Clay prototyping follows hand made sketches in order to better evaluate shapes, external surfaces, volumes and light shades. A clay or chulk model modification could be very expensive in term of time, greatly reducing the capabilities of a “fast prototyping”.

Once the designer is satisfied, the full model will be digitized for CAD surfacing [13]. Also this step represents a very time wasting phase, due to digitizers require specialized human activity; on the other hand, softwares for surface reconstruction need computation time and high cost workstations.

The above described process part can be graphically represented by the following diagram (Figure 1):

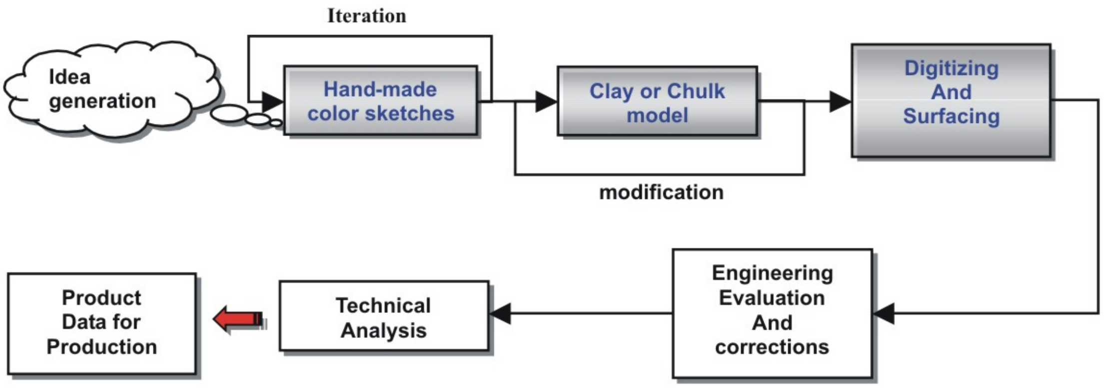

Figure 1. Traditional Design pr ocess workflow.

1.2. All-in-one concept.

In this panorama, VISM may be the way to skip clay and chulk model and make the designer working directly on the virtual model, like a physical full scale model, greatly simplifying also the integration with CAD packages.

Opposing to the traditional workflow, described in Fig. 1, VISM leads to a CAD – VR integration better represented in Fig. 2. Virtual Reality is used to visualize and modify a 3D model based on NURBS surfaces. Stereographic vision makes the designer feel in 3D like in front of a concrete clay prototype. 3D tracking devices provides interaction with models, selecting parts and modifying.

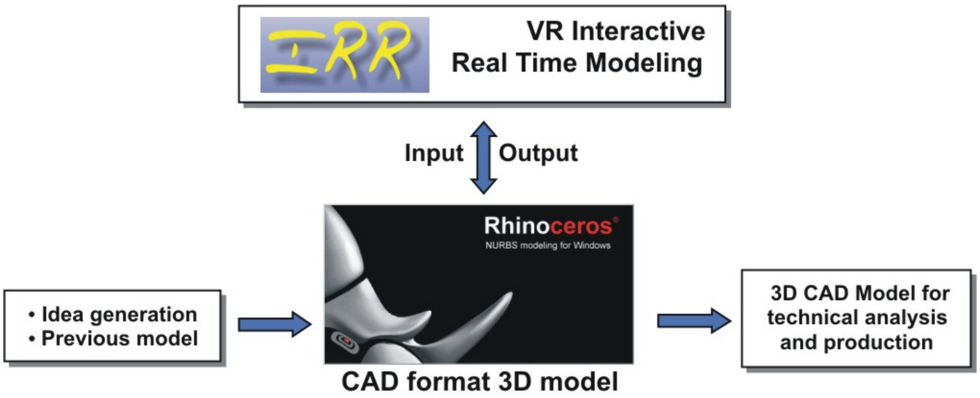

Figure 2. VR Design process workflow.

1.3. Full-scale modeling vs. reduced scaled model.

A big deal of work in this development of VISM has been spent in calibration activities in order to provide the designer not only a 3D feeling, but also a full scale model. Sometimes scaled models inside to workstation monitors may prevent the designer from a correct evaluation of the final effect of the model. Thanks to 7.5 m wide screen, IRR is capable to show full screen model up to 7 m.

2. VR ENVIRONMENT FOR FULL SCALE MODELING.

2.1. IRR at V-Lab.

Immersive Reconfigurable Room (I.R.R.) is a Virtual Reality surround environment, completely developed at V-Lab (http://v-lab.ingfo.unibo.it/hardware5/hhardwareframe.htm) – University of Bologna – Forlì. As shown in figure 4, IRR is based on 3 rear – projected translucent screen (2.5 x 1.9 m each), installed on a cubic structure, easy to translate and rotate. Thanks to this feature, IRR may take one configuration from “full flat” (all three screens aligned), like “wall”, and “room like position” (screens at 90° each other).

The system is driven by a PC cluster based on graphic servers (2 x PIII 933 MHz) each controlling a videoprojector and a master computer linked with a ultrafast Ethernet connection (1 Gbit/s). Stereo vision is provided both by high-end graphic accelerators and a strong output signal syncronization.

Figure 3. IRR at V-Lab.

2.2. Stereo vision.

The stereographic vision is achieved by Stereographics Crystal Eyes performing active stereoscopy. Several syncronized emitters have been installed on top of screens in order to cover a wide range of operator's positions.

Furthermore a dedicated client-server software package has been developed with the objective of splitting the wide camera FOV (Field Of View) (140°) rendering over the 3 screens with non sensible delay between graphic servers.

2.3. 3D Tracking for manipulation.

3D tracking is provided by Polhemus Fastrak with 3 receivers each returning 6 DOF (relative to x, y, z, yaw, pitch, roll) for both hands and operator's head.

Also two gloves, provided with electrical contacts on fingertips, may achieve the designer to activate several commands simply by pressing thumb against one of the other fingers.

2.4 Software.

The main concept introduced in VISM has already been widely described in a previous paper [1]. VISM was born with the leading idea of developing a very easy-to-use unique modeling command for surface modification and manipulation in Virtual Reality.

It is based on a control point repositioning, performed by a high frequency callback function, in order to make the surface assume the shape of the modeling tool.

We can schematically resume the algorithm in the following steps, referring to [1] for a more exhaustive explanation of each of them:

- Projection of control points on tool curve on the surface -> points on the surface;
- Determination of the parameters corresponding to the points->u,v parameters;
- For each of the parameter couple, determination of the surface control point with the maximum influence;
- Repositioning of that point, eventually filtered by smoothing algorithm.

In addition, the original VISM interface has been improved in order to achieve a better integration with commercial CAD systems.

Due to NURBS trimmed surfaces is widely considered a standard to mathematically describe a 3D surface model, the basic modeling kernel, developed on top of Open Inventor graphic libraries, has been enriched with the integration of OpenNURBS toolkit, a front-end interface to read and write 3dm Rhinocerous models. A great work has been done to transparently manage trimmed Rhino surfaces as a single node in the Inventor scenegraph.

In spite of parametric information lack in Rhino model, the dataset produced can be considered a good trade-union between CAD and Virtual Reality environments.

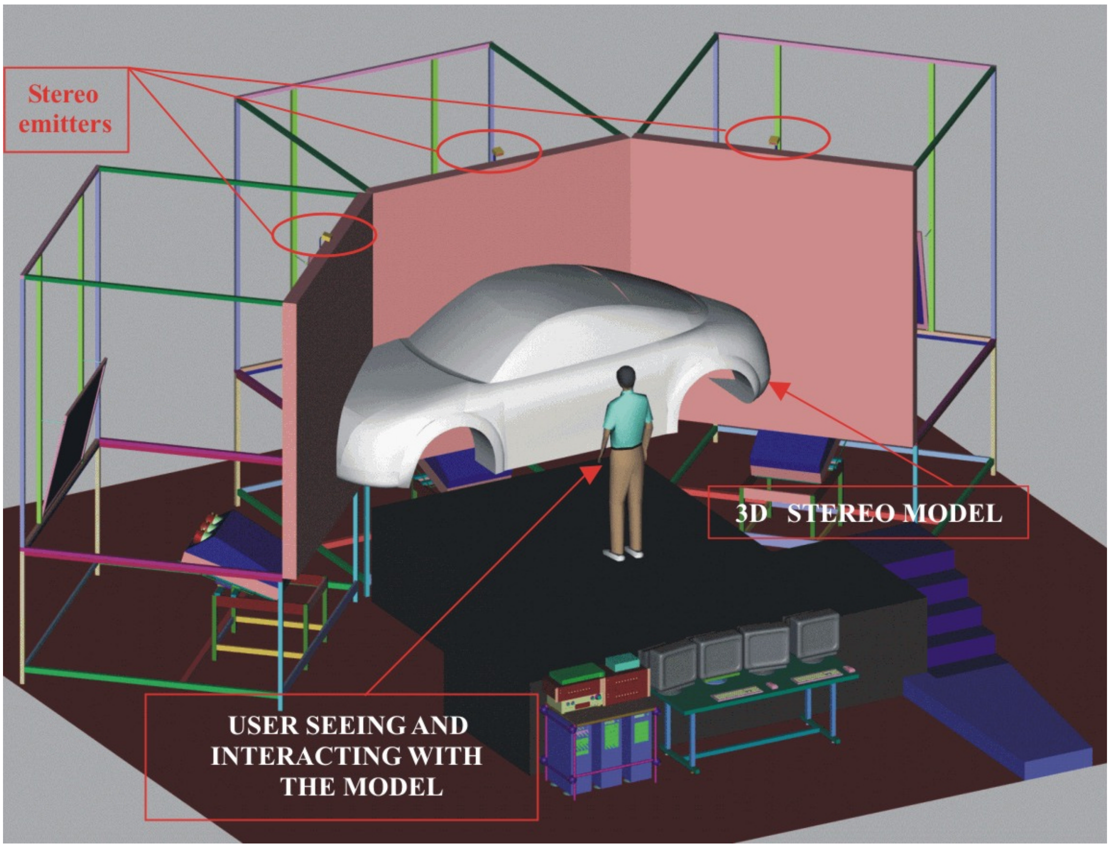

Figure 4. IRR Lay-Out.

3. V.I.S.M. FOR FULL SCALE MODELING.

3.1. Calibration.

In order to perform both full scale visualization and full scale movements, there are two conditions to verify: 1) the model in the CAD file should have real dimensions in meters; 2) to make user hands' movement correspond to movements in the virtual space, a system calibration is required. Polhemus Fastrak acquires positions in inches, while Inventor default unit are meters. For this reason it's been necessary to introduce in the Inventor scenegraph a converting node from inches to meters, only for data acquired from Fastrak.

3.2. Modeling commands.

In this section an extended list of implemented commands is described.

Automatic Model Loading. The file loading routine is performed by default at program start. A sophisticated parser has been implemented due to the presence in Rhino model of multiple trimmed surfaces. Each surface needs to be stored in a separated node in order to be singularly modified.

Select surface to model. The first action the user may perform in order to operate, is the selection of a surface frome the model to be modified. This is done by keeping the Second Left Pinch contact pressed and at the same time "touching" with the left hand proxy the desired part. When an intersection occurs, the color of the proxy become red; at this point, by pressing the second Right Pinch contact the surface is selcted and its colour turns into green, to indicate the performed selection.

Activate modeling. Once a surface is selected, the user can begin to modify it, by keeping pressed the first Right Pinch contact and, at the same time, by passing the shape tool over the surface itself.

Examine model. The user can, whenever he wants, examine the whole model, simply by keeping the third Left Pinch contact pressed and moving the left hand. The model follows left hand's translations and rotations and this gives the user the complete freedom of study his work from every point of view.

Undo last surface modeling. After selecting and modifying one of the surfaces, it may occurr the need of undoing the modeling action, in order to restore the initial configuration of the given surface. This can be done, at every time, by pressing the third Right Pinch contact; in this way the last selected surface is restored to its previous configuration.

Edit tool shape. The tool shape is modellable in an interactive way, simply by keeping the first Left Pinch contact pressed and touching with the left hand proxy the tool spheres. In this way the spheres follow the left hand proxy and the tool curve, a NURBS curve, is deformed accordingly.

Save model to Rhino format. At the end of all modeling operation, once the designer is satisfied, he can write the whole model to a 3dm output file simply by pressing the fourth Left Pinch contact. The model, is now ready for CAD modifications or analysis, or conversion to other file formats, as those for rapid prototyping machines (STL, etc.).

4. RESULTS.

We tested the application modifying a surface model of a well known sport car: Audi TT. Figure 5 shows the steps of a design session.

In the following steps a brief description of a modeling session in VISM:

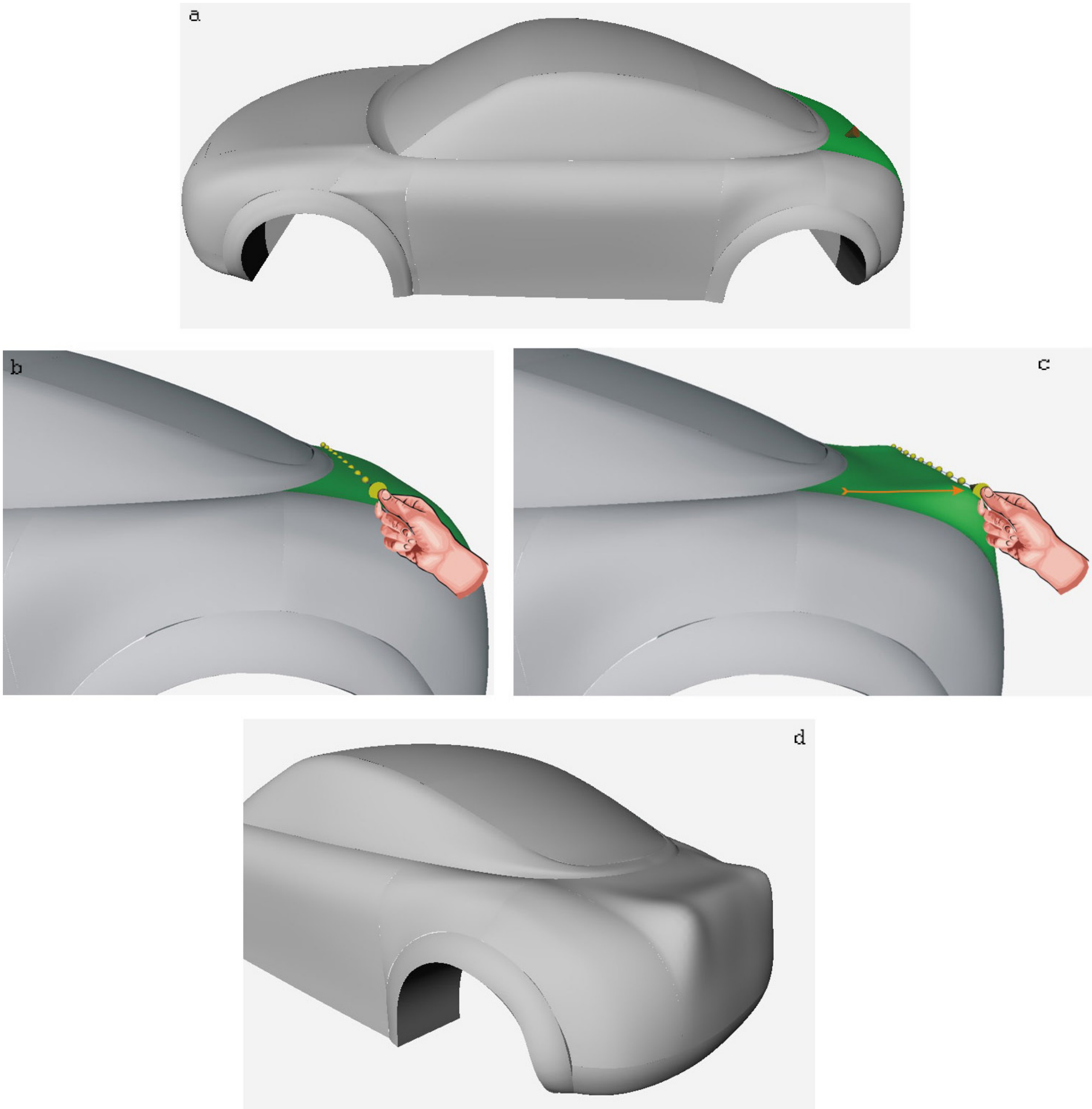

Figure 5. Steps of a Design session. a) Selection of the surface to modify. b) Starting of the modeling action. c) End of the modeling action. d) Final model.

a. **Selection** of the surface to modify. The red cone represents user's left hand; he touch the part of the model he wishes to modify and this become the active surface (green color).
b. **Starting** of modeling action. The yellow cone represents the right hand and a virtual shape tool is connected to it. The tool is a NURBS curve (the blu line) and its control points are represented as yellow spheres. In this case the tool is almost a straight line.
c. **End** of modeling action. Simply by moving the tool (connected to the right hand), user performs a "global surface shaping".
d. **Final** model. Once the designer has completed the modeling action, the model is saved as a 3dm Rhino file and is ready for further operations.

5. CONCLUSIONS.

Tests performed on the IRR demonstrate the efficiency of this new conceived design environment. In details, it permits a notable time saving. It opens new never explored ways to the design methods; the designer has got the possibility to do by himself all the modifications to the model, without the need to demand them to a clay modeler. This gives him the total control of the design process.

The modeling algorithm is very fast and robust, since it permits the real-time modeling of every shape, from the simplest to most complex ones, without any troubles. However there may be, for future software releases, some emprovements in order to better the overall shape quality, in term of immediate perfect correspondence of the user's hands movement to the surface shaping.

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