FROM CAD MODEL TO HUMAN-SCALE MULTIMODAL INTERACTION WITH VIRTUAL MOCK-UP

An Automotive Application

Damien Chamaret, Paul Richard and Jean-Louis Ferrier
Laboratoire d'Ingénierie des Systèmes Automatisés (LISA), Université d'Angers
62 Avenue Notre Dame du Lac, 49000 Angers, France
damien.chamaret@univ-angers.fr, paul.richard@istia.univ-angers.fr, ferrier@istia.univ-angers.fr

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Abstract: This paper presents and validates a new methodology for the efficient integration of CAD models in a physical-based virtual reality simulation. User interacts with virtual mock-up using a string-based haptic interface that may provides haptic sensation to both hands in a large workspace. Visual and tactile displays provide users with sensory feedback and improve both user performance and immersion. Stereoscopic images are displayed on a 2m x 2.5m retro-projected screen and viewed using polarized glasses. The proposed methodology implemented in a low-cost system, has been tested with an automotive application task. However, the presented approach is general enough to be applicable to a large variety of industrial applications.

1 INTRODUCTION

Most research on virtual environments dedicated to Computer Aided Design (CAD) application are confronted to difficult problems related for instance to real-time 3D simulation including physics, integration of multisensorial feedbacks, etc. Another problem to overcome is the transformation CAD models to virtual reality (VR) models.

In this paper we present and validate a new methodology for an efficient integration of CAD models in a physical-based virtual reality simulation that provides the user with multimodal feedback. Haptic interaction is based on the SPIDAR system illustrated in Figure 1 (Bouguila et al. 2000). The methodology has been tested with an automotive application task. However, the presented approach is general enough to be applicable to other tasks and industrial applications requiring realistic interaction.

2 RELATED WORK

2.1 Visuo-haptic VR Configuration

Projection-based Virtual Environments such as CAVEs™ (Cruz-Neira et al., 1993) Workbenches (Krueger and Froehlich, 1994) or immersive wall (Richard et al., 2006) are the most popular VR configurations. They provide a large number of performance/immersion factors like stereoscopic visualization, large screens, large manipulation space, etc. However, adding force feedback to these configurations without degrading their performance/immersion factors is not an easy task.

Most general purpose haptic devices, like the PHANToM (Massie and Salisbury, 1994) are often used with desktop visualization configurations. Most of the time, they are not able to adapt to VR configurations, leading to a degradation of some of the performance/immersion factors of the VR configuration.

Some general purpose haptic systems have been integrated within large screen projection-based VR configurations (Brederson et al., 2000), (Grant and A. Helser, 1998), (Garrec et al., 2004).

The only large screen projection based VR configurations equipped with non-intrusive haptic system involves the SPIDAR system (Bouguila et al., 2000), (Tarrin et al., 2003), (Ishii and Sato, 1994) (Richard et al., 2006).

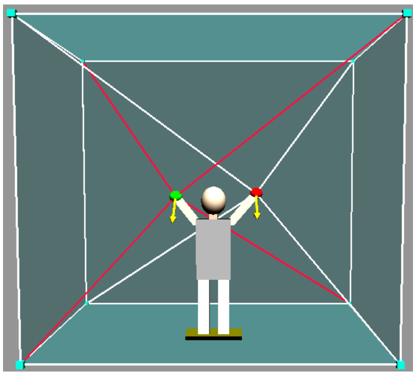


Figure 1: Schematics of the human-scale SPIDAR system. This non-intrusive haptic device provides force feedback to user's both hands while moving in a large-scale workspace.

2.2 Grasp Feedback

Grasp feedback includes both tactile and shape feedback. Haptic systems exist for both but they are different and rarely integrated.

The best known solution for providing a realistic grasp feedback consists of using props. Props are physical objects held in hand by the user. Props have been proposed for tasks such as application control (Coquillart and Wesche, 1999), 3D objects manipulation (Hinckley, 1994), (Tarrin et al., 2003), and design. Several psychophysics experiments demonstrate the benefits of props (Hinckley, 1994). Props provide stable grasp feedback, intuitive manipulation as well as realistic shape and texture rendering.

Props do not allow sensation of the collision with a surface touched by the prop itself. Combining props with force feedback is again a difficult task because most force feedback systems can't attach props in a flexible way.

The next section of the paper presents a CAD to VR methodology. Section 4 describes the developed prop-based stringed haptic configuration. An industrial application is presented in Section 5. Section 6 concludes the paper and describes future work.

3 CAD TO VR METHODOLOGY

The CAD to VR methodology is illustrated in Figure 2. Our methodology involves different steps such as model tessellation (1), model integration (2-3) and sensorial feedback (4-5-6). The CAD to VR model transformation is illustrated in Figure 3.

3.1 Model Tessellation (1)

The first step was to choose an appropriate common exchange file format between standard CAD software (such as CATIA) and 3D general purpose modelling software (such as 3D Studio Max). The tessellation procedure consists in decreasing the number of faces without degrading the 3D shape of the model.

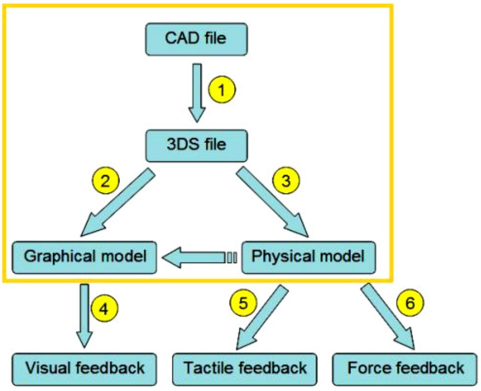


Figure 2: Schematics of the CAD to VR model transformation.

3.2 Model Integration (2-3)

Many loaders may be used to integrate 3D models in a real time C/C++ 3D application. However, this leads to graphic simulation in which the virtual objects do not have physical properties. In order to give physical properties and behaviour to the model, we developed a single procedure that allows to automatically obtain both graphical and physical models of loaded objects. Moreover, the physical model on which is based the real time simulation, exactly corresponds to the graphical one.
The physical model is built using PhysX^{TM} an efficient well-known open source physic engine from AGEIA (http://www.ageia.com).

3.3 Sensorial Feedbacks (4-5-6)

In order to increase both realism of the simulation and operator performance during interaction with the virtual mock-up, different sensorial feedbacks are provided. Simulated forces are calculated by the physic engine and displayed on user hand using the SPIDAR system.

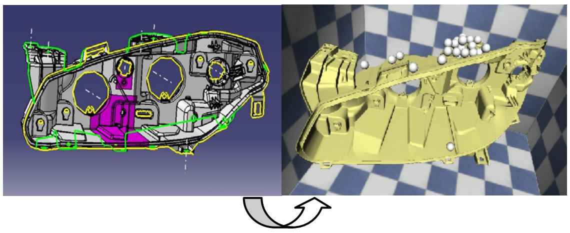
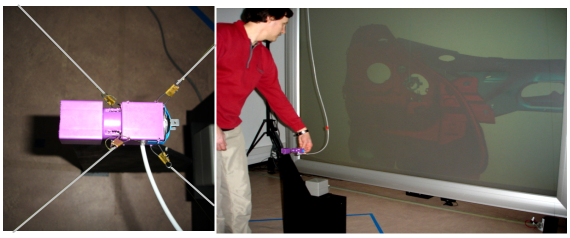


Figure 3: illustration of a CAD model transformation to a physicalized VR model.

4 PROP-BASED STRINGED HAPTIC INTERACTION

In the context of the automotive application described in the following section, a prop has been integrated into the SPIDAR system in order to provide both realistic and low-cost grasp sensation while performing the task. Figure 4 shows the attachments of the prop to the SPIDAR (Figure 4a). As shown in Figure 4b, the user grasps the prop (a real car lamp is integrated into a plastic part). In order to increase accuracy, both position and orientation of the prop are obtained using a Patriot 3D tracking system (http://www.polhemus.com).



(a) (b)

Figure 4: Top view of the prop attached to the SPIDAR system (a), grasping of the prop by a user (b).

5 AUTOMOTIVE APPLICATION

Our VR human-scale platform opens the door to many CAD applications requiring realistic integration modalities such as visualization, audio, force and tactile feedback. One such application, from the automotive industry, is described in this section. It concerns accessibility and maintenance of car lamps.

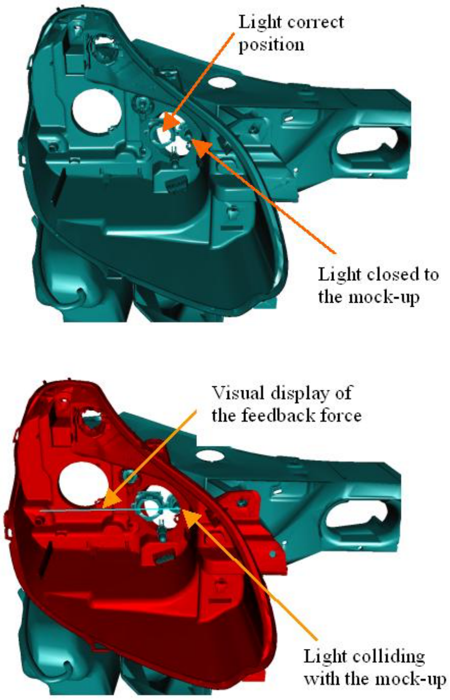


Figure 5: Illustration of the final stage of the task: the application provides both haptic and visual force feedback to the operator.

5.1 Description of the Application

During the conception stage, car designers have to make sure that anyone will easily be able to achieve maintenance task concerning car lamps. In this context, special attention has to be paid to the following aspects:

- Accessibility: to be able to reach and pick-up car lamps,
- Replacement: to be able to remove broken lamps and replace them by new ones.

Currently, the only solution is to build a mock-up of the car. The process is of course slow and expensive. A cheaper and faster solution consists in realizing the tests on virtual mock-ups. An additional advantage is that it can be done earlier in the conception process, which eases modifications. Our methodology associated to the human-scale haptic virtual environment highly contributes to the widespread use of virtual mock-up in a realistic simulation.

This methodology has been validated in the previously mentioned context (car lamps maintenance). The Figure 5 shows screenshots of the virtual mock-up during the maintenance task. The final stage of this task involves the correct placement of a car lamp. As illustrated on the bottom screenshot, both collision detection and force feedback are visually displayed respectively using a red colour and clear blue line (orientation of the force).

5.2 Hardware and Software Architecture

As opposed to most of the existing virtual reality human-scale platforms that are based on clusters, our hardware architecture is based on only one Personal Computer (bi-Xeon 5150, 4Go RAM and 8800 GTX Graphic board).

The frame rate is however, in the described application (600 000 Faces), maintained to about 30 frames per second. Thus, the use of a physical Processing Unit is not necessary.

6 CONCLUSIONS AND FUTURE WORK

We presented and validated a new methodology for the efficient integration of CAD models in a physical-based virtual reality simulation. User interacts with virtual mock-up using a string-based haptic interface that may provides haptic sensation two both hands in a large workspace. Visual and haptic displays provide users with sensory feedback and improve both user performance and immersion. Stereoscopic images are displayed on a 2m x 2.5m retro-projected screen and viewed using polarized glasses. The proposed methodology has been tested with an automotive application task. However, the presented approach is general enough to be applicable to other tasks and industrial applications.

In the next future we plan to add a virtual hand with physical properties to allow dexterous manipulation of 3D objects. We will also replace the magnetic tracking system by an optical MOCAP solution. We will also use our methodology for other CAD applications.

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