

3D interaction techniques in Virtual Reality Applications for Engineering Education

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Abstract

This article is an overview of 3D interaction techniques with virtual objects, perception of virtual objects and some aspects about hardware devices, software and technologies used in Virtual Reality Applications for Engineering Education. The solution presented uses open source software (CHAI3D) and low-cost hardware that allow quickly integration into current mechanical curriculum.

Keywords: 3D interaction, educational haptics, engineering education

1. Introduction

Qualifications in mechanical engineering require skills and technical competences with a high degree of complexity which involves a modern curriculum, instruction based on student-centered strategies that encourage motivation and interest developing critical thinking and problem solving through active involvement in learning. It will combine individual learning activities with the ones implying teamwork, traditional methods with the modern, interactive ones. The introduction of teaching in virtual reality techniques can be one possible answer to all these requirements.

Either old or recent studies consider that the use of virtual reality methods add value to the traditional learning methods in the classroom, first by the fact that participants face specific learning /training situations required by the application producer. His ultimate goal is to improve methods of learning, training and education (Schroeder, 1995), (Youngblut, 1998), (Inoue, 2007). According to (Jacobson, 2006) results that immersive 3-D VLEs, may provide 'value-added' learning over 2-D technologies used to deliver equivalent educational content. In recent years, the ubiquity of multimedia and Internet-capable PCs has led to a resurgence of interest in web-based virtual reality (Dalgarno and Lee, 2010).

Designing didactic applications based on virtual reality initially involves two important aspects, namely:

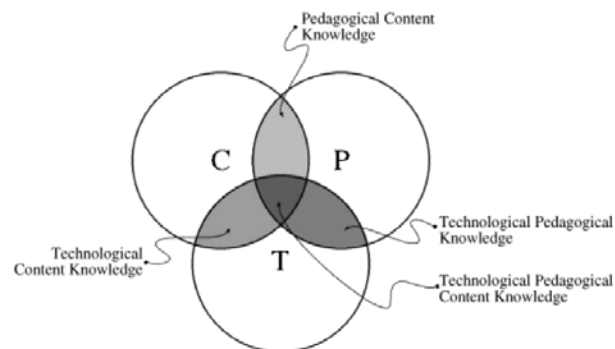
- developing a pedagogical model;
- specifying necessary hardware and software technologies.

2. Developing a pedagogical model

A traditional learning environment integrates courses, formal and informal resources, a management and communication system, all in a classic teaching model. Similarly, a virtual reality learning environment has to integrate functions like: information, communication, collaboration, learning and management. Developing a pedagogical model is difficult because curriculum goals, classrooms and teachers vary from case to case. The relationships between content, pedagogy and technology are complex and nuanced.

The chosen solution must be in line with patterns like Technological Pedagogical Content Knowledge (TPCK) proposed by (Mishra and Koehler, 2006) – figure 1. Their “framework emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology. In this model, knowledge about content (C), pedagogy (P), and technology (T) is central for developing good teaching. However, rather than treating these as separate bodies of knowledge, this model additionally emphasizes the complex interplay of these three bodies of knowledge.” (Mishra and Koehler, 2006, pp.1025).

Figure 1. Pedagogical Technological Content Knowledge. The three circles, Content, Pedagogy and Technology, overlap to lead to four more kinds of interrelated knowledge Mishra & Koehler (2006).



The pedagogical model specific for learning through virtual reality must highlight the new skills and attitudes to be acquired (based on formal professional standards), the level at which the student is, skills to be practiced through repetition and practice, personal learning opportunity, the skills they need to practice, the possibility that through repetition and practice in the virtual environment to acquire new attitudes and competences, learning opportunity in their own space. The solution might be to integrate the lessons based on virtual reality on a platform like Moodle that allows organization and administration of educational material. Moodle is a Course Management System (CMS), also known as a Learning Management System (LMS) or a Virtual Learning Environment (VLE) and it is free.

3. Specifying necessary hardware and software technologies

The solutions chosen for the hardware and software technology are very different, depending on costs. A typical VR system results from the integration of a wide variety of components – figure 2, in a system that mainly solves problems such as: graphics hardware, 3D modelling, visualisation and rendering software, tracking technology, interaction devices, motion control, collision detection, network, display systems. The components have some specific requirements for a real time interactions, sufficient graphical rendering performance and rendering of other senses such as haptic (touch) or sound information.

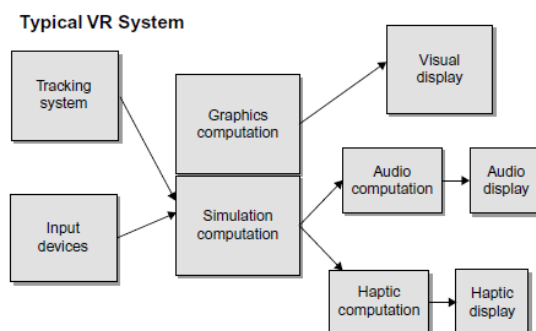


Figure 2. Typical VR System (Craig, 2009)

In order to implement virtual reality in the training process of the mechanical disciplines from the technical high school curriculum, as a first step, we have acquired the necessary components of a low – cost system: a head-mounted display or a pair of stereoscopic glasses to begin with, a pair of gloves DG5-Vhand, the appropriate interface between them and the virtual environment (VRML), a computer system and the corresponding software.



Figure 3. Components of a low – cost VR system: head-mounted display and DG5-Vhand glove

4. 3D interaction

Interaction is an important characteristic of any VR system. The user may be able to manipulate 3D objects into virtual environment. According to (Poupyrev, 2000), the design of manipulation techniques depends on interaction tasks and several variables.

The basic tasks are:

- position, the task of positioning an object from an initial to a final, terminal, phase;
- selection, the task of manually identifying an object;
- rotation, the task of rotating an object from an initial to a final orientation.

Variables that affect manipulation are: distance to the object, object size, required translation distance, amount of rotation, object's density and others. Most of the manipulation techniques are based on a few interaction metaphors or their combinations. A taxonomy (Poupyrev, 2000) of manipulation techniques is the following:

-by metaphor:

- o Exocentric metaphor: World –In – Miniature, Scaled – world grab, Voodoo – Dolls
- o Egocentric metaphor:
 - Virtual Hand metaphor: “Classical” virtual hand, Go-Go, Indirect, stretch Go-Go
 - Virtual Pointer metaphor: Ray – casting, Aperture, Flashlight, Image plane

-by component - Manipulation:

- o Object Attachment: attach to hand, attach to gaze, hand moves to object, object moves to hand, user/object scaling
- o Object Position: no control, 1-to-N hand to object motion, maintain body – hand mappings, indirect control
- o Object Orientation: no control, 1-to-N hand to object motion, other hand mappings, indirect control
- o Feedback: graphical, force/tactile, audio

In our pilot system the problem of manipulating the parts with virtual hands was solved (the actual hand movements made with DG5-Vhand for operations such as taking a piece with virtual hands and identifying constructive guidance through visual observation and acquisition of two objects or two components in order to simulate an operation of mounting). Interaction with the virtual scene is achieved by using two VR gloves type-Vhand DG5. The development of the application is carried out under the form of C++ projects, gloves being included in the project by software libraries:- HandManager.lib, VhandManager.dll, Project.h, DataGlove.h, delivered with the gloves. The files are intended to be used with Windows 98/2000/XP and Vista environments, and geometric modelling was done in Solidworks.

5. Haptic interaction

Understanding concepts and phenomena delivered in the training process of the mechanical disciplines from the technical high school curriculum can be improved by "force feedback". The term describes kinesthetic / vibrotactile feedback and is incorporating hands, upper torso, head and other parts of the body.

Haptic devices allow users to touch, feel and manipulate three-dimensional objects in virtual environments. Haptic devices are an input-output of the devices, meaning that they track a user's physical manipulations (input) and provide realistic touch sensations coordinated with on-screen events (output). Examples of low-cost haptic devices (Sharma and Gupta, 2011):

- Haptic Paddles
- Haptic knobs
- Novint Falcon
- Force Feedback Gaming Joysticks
- SensAble's Omni Phantom

To make haptic interfaces accessible to small groups of students in the training process of the mechanical disciplines from the curriculum, the device must be low cost and relatively small. (Grow and Okamura, 2007). Our pilot system allows haptic interaction via a low cost Novint Falcon device. – figure 4.

6. Experiment

In (Starețu and Dudulean, 2009) we presented an experiment which aimed an evaluation of 3D object manipulation using a virtual hand. Effectiveness of the metaphor strongly depends on the sensory channels they refer to and on the users characteristics. The haptic device inserted into the application aims to increase the efficiency of the interaction metaphor. The solution chosen is

low - cost and the applications software, Chai3D, is open - source.

First was made an application, a haptic game (Towers of Hanoi), allowing students a training on haptic device. – figure 5.

Next we used several virtual objects: a parallelepiped, a cube, interchangeable gears, and a spindle. The student can change the orientation and position of all the component elements of the virtual environment in real time, with haptic feedback. Models have been developed in .3ds or .obj format and loaded in CHAI3D through Visual Studio. – figure 6.

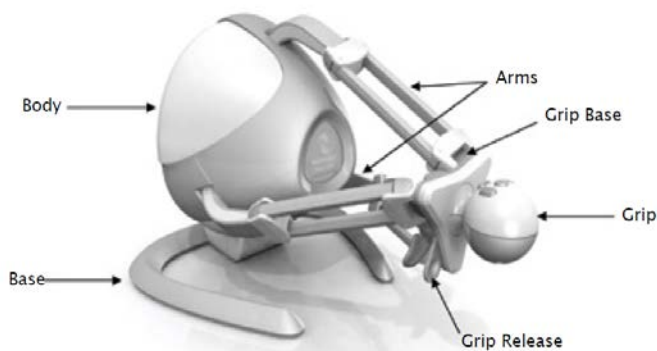


Figure 4. The Novint Falcon low – cost haptic device

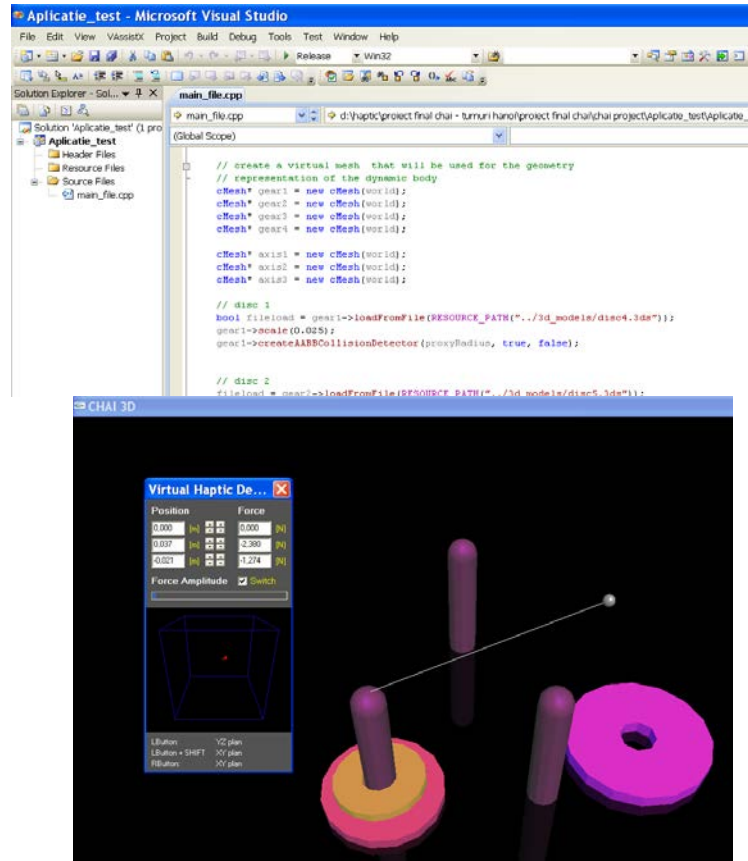


Figure 5. A haptic game in Chai 3D

Chai3D is an open source set of C++ libraries for computer haptics, visualization and interactive real-time simulation. Chai3D supports several commercially-available three-, six- and seven-degree-of-freedom haptic devices and makes it simple to support new custom force

feedback devices. Chai3D is especially suitable for education and research purposes, offering a light platform on which extensions can be developed. (<http://www.chai3d.org>).

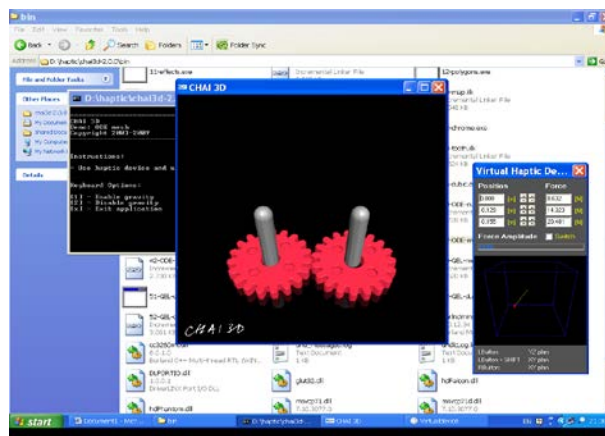


Figure 6. A haptic educational application in Chai 3D

7. Conclusion

Based on those presented we consider:

1. haptic feedback through a low cost and relatively small device is a solution to increase effectiveness in interaction
2. the involvement of haptic feedback in teaching showed that the students spent more time exploring the virtual objects; these are perceived and

conceptualized similar like in real life, the result is increased interest of students.

3. the student behaviour changes through haptic feedback; the method encourage motivation and interest, develop critical thinking and problem solving through active involvement in learning

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