PILOT STATION FOR TRAINING PROCESS SPECIFIC TO DISCIPLINES OF APPLIED MECHANICS USING VIRTUAL REALITY

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Abstract: First, the paper discusses issues regarding training in mechanical design using CAD software to develop the geometric model of the components, the simulation possibilities of functioning in the case of the model developed, when it may become part of a virtual setting. In the second part in the paper we present in brief the reasons for the introduction of virtual reality with immersion in the processes of theoretical and practical training in mechanical disciplines. There are some considerations on the methodological implications and we propose an extension of the model Wegener. We describe a pilot station which is in progress to test the use of virtual reality in the training activities concerned. We present the first achievements in this direction namely: proper populating of the virtual setting, interconnection of Cyber Glove gloves with the virtual setting and manipulating of virtual parts for visual observation and simple assembly operations.
Keywords: CAD, geometric model, teaching method, virtual reality, virtual setting

1. INTRODUCTION

The major challenges in the educational process are: first getting as fast as possible to an appropriate competency corresponding to requirements of various activities on the labour market, in continuous diversification and increase of the degree of complexity, and on the other hand permanent modernization of methods, techniques and equipment used in the instructive educational process e.g.[1,2]. These requirements are of great importance in the training of technicians at the high school level, respectively of the specialists - engineers at the university level, particularly in advanced technical specialties: mechatronics, automation, electronics, etc. In this context, due to increased requirements for skills in these areas, it is necessary to introduce methods, techniques and equipment of last generation.

These are necessary because the modern engineering, respectively re-engineering are so specialized and so complex products that it is difficult for one person or team to design a product and the general practice of design – re-design has imposed as a generalized manner the use of the computer, the software acting as the catalyst that revolutionized this process. Initially the computer was used for the design, technology that later became computer aided design (CAD). Subsequently there were created 3D representations of references that are part of the products composition. The next phase was the takeover of these models and their execution on numeric command machines, and finally their processing on machines assisted by the computer.

So, graduates, especially those of level 3, technological high school, who qualify in technical professions must, under the standards of training, be able to perform tasks of a technical nature, rather difficult to achieve, in the conditions of poor facilities and many times outdated, of the school workshops or local economic agents. e.g. the qualification "Mechatronics Technician", provides skills and abilities to enable the graduate the achievement of technical tasks of assembly, putting into service, maintenance, operation, and repair of mechatronics systems, testing of prototypes, conception and design of schemes for mechatronics assembly equipment, ensuring the technical control of installations, maintenance of mechatronics systems for their functioning according to specifications and regulations in force e.g. [3].

An effective solution, modern and of perspective, concerning the issues shown, could be the use of virtual reality in education e.g. [4]. It is clear to most experts that the future belongs to 3D interfaces, hesitations being related especially to the cost of the equipment and its quality (resolution, response time, etc.).

2. BASIC CONCEPTS ON THE USE OF VIRTUAL REALITY IN TEACHING ACTIVITIES

The idea of using virtual reality in educational activities is not new, there are relatively thorough studies carried out in this respect e.g. [5], but far from the total settlement of the problems generated by this approach.

Based on what has already been achieved until now it is considered that the use of virtual reality methods add value to 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 being to improve methods of learning, training and education e.g. [5].

Virtual reality in teaching involves several aspects, namely:

-Developing a pedagogical model
-Specifying hardware and software technologies necessary;
-Developing a guide to design applications for the professor;
-Developing a user guide for the applications;
-Developing assessment instruments

The pedagogical model, specific to learning through virtual reality must be conceived in cognitive and affective terms so as to transmit the user:

- the level at which he is;
- the skills they need to practice;
- the possibility that through repetition and practice in the virtual environment to acquire skills, abilities, new attitudes and competences
- learning opportunity in their own pace

The applications designed will be oriented to technical skills or the ability of the standard of professional training which the student is going to master. It thus allows the development of standardized software packages that appear with intelligent tutorials for training and evaluation. The role of the teacher in the classroom acquires in this way a plus in the partnership plan and of guidance of the trained one.

Extremely important is the timing since the teacher's intervention is needed and what is the teacher's role in the application. The compliance with the aspects shown will provide an understanding of learning through virtual reality and will ensure the acquiring of the competences envisaged e.g.[5].

As a training process in which the computer is involved, teaching applications with virtual reality techniques, in that regard should be integrated into theories and models of computer-assisted instruction. Specialty literature provides a rich bibliography in this regard e.g. [6]. There are a multitude of names and terms, the dominant being the acronym CBT (Computer Based Training) of the model proposed by Wegener e.g.[7], see Figure 1.

A key step in learning CAD design of mechanical - mechatronic products is modelling and simulation of mechatronic – mechanical systems, including exact geometric modelling of the components, restrictions and conditions of service. 3D geometric models can be classified as follows:
- Oriented on edges (wireframe);
- Oriented on surfaces (surface model);
- Oriented on volume (solid model).
Solid models are calculated by the following techniques:
- Constructive solids geometry (CSG);
- By borders (B-rep);
- By spatial enumeration (octree ...);
- By sweeping, etc.
- Analytical (ASM - Solid Analytic Model);
- Parametric / procedural.
The shape of geometric patterns is based on a set of elementary forms – prism, cylinder, cone, and sphere – from a combination of whom (by Boolean operations) we obtain the desired result. These forms are called primitive and can be found in any CAD system that allows 3D modelling.

Modelling usually begins by exact geometric modelling of the system components. For this we use CAD software that allows modelling (3-D), of components forming the mechanism, for example, SolidWorks, Catia, Pro/engineer, Solidedge etc. We presented in Figure 2, the geometric model of a auto front axle suspension mechanism developed in SolidWorks e.g.[8,9].
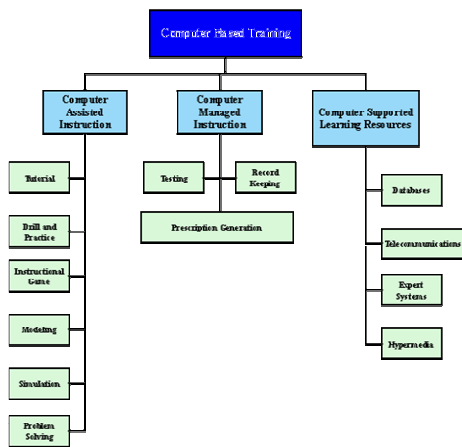

Figure 1: Wegener CBT structure chart.

Figure 2: Mechanism of auto front axle suspension.

First, each component was modelled in part after that they were assembled. The software allows both the realization of the assembly of the mechanic system components and their exploding, i.e. the deployment of each component separately to suggest assembly.

Once the geometric modelling completed, we pass to the design of a control system (mechanical, hydraulic, pneumatic, and electric) that will finally, through a simulation, analyze how each component affects the operation and the way it interacts with other parts. From one stage to another of the process we use more software: e.g. for geometric modelling SolidWorks, to achieve control and command Simulink, and for simulation and visualization - virtual reality techniques.

To study the behaviour of the model under real operating conditions it is necessary its dynamic modelling. The software used is Matlab (Simulink), whose module Simmechanics allows the dynamic modelling of the CAD models developed in SolidWorks. To do this, in advance is required to export the CAD model to Simmechanics with the program Simmechanics - CAD - Translator. The model is developed using the method of multi – body systems according to which the model is composed of bodies linked by joints. The model Simmechanics equivalent to the geometric model will contain bodies linked by joints, coordinate systems attached to each body, and their constraints. Each body corresponds to a block element, and Simmechanics blocks can be connected to Simulink blocks so that the result can be saved and reused in various fields. To create the model Simmechanics we list the weight characteristics for each body and the characteristics of each link defined in SolidWorks assembly. The listing is saved in an XML file Simmechanics.

This file enables the automatic creation of an appropriate model Simmechanics through a Matlab command. After creating the automatic model Simmechanics it can be verified by running a simulation. Note that not all models can be transformed because of the restrictions of SolidWorks' elements.

Viewing the simulation in Simmechanics does not offer quality; therefore a solution of viewing is *virtual reality*. For this, Matlab has the Virtual Reality Toolbox module which allows views and direct interactions with the dynamic model. The modules MATLAB ® and Simulink ® combined with virtual reality graphics can control position, rotation and the scale of the images defined in virtual reality, the result being a quality 3D animation. 3D scenes are described in VRML language. Geometric patterns made in SolidWorks can be saved directly into the VRML format, the software enabling that in Figure 3.

The output of the Body Sensor block contains the matrix of position and rotation of the item, which will be transformed into an axial-angular shape which VRML uses to define the position of bodies. Transformation is achieved by using blocks of the Virtual Reality Toolbox library. The final step is coupling the model Simmechanics to the Virtual Reality setting using the VR Sink block of Virtual Reality Toolbox. Once the connection made, the simulation can be started and the animation can be seen in Figure 4.
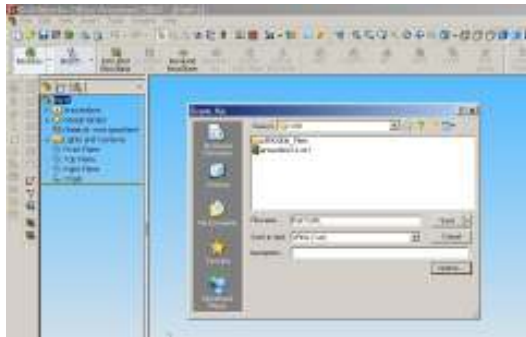

Figure 3: Saving SolidWorks model in VRML format.

Figure 4: Auto front axle suspension mechanism connected to the virtual scene.

The Simmechanics model and the simulation in Virtual Reality Toolbox provide information on the dynamic behaviour of the mechanical components. Simmechanics model also can be used to design command items of the mechanical components of the model or for modelling in other areas. For example, a controller can be implemented on a hydraulic drive or an electric motor.

Correspondingly, Matlab provides the modules Simhydraulics, Simpowersystems and Simdriveline allowing modelling in different areas and simulation of the result in the Simulink environment.

To improve the possibilities of handling the model and navigate on the virtual setting one can add to the system hard elements of virtual reality specific view.

Compared with the CAD solution and its corresponding Computer Based Training - Wegener model and its components, it should be made clear that virtual reality does not share simple quantitative 3D equipment (gloves, goggles, headphones). By the fact that virtual reality is a computer generated environment where by immersion in the trainee performs activities in real time, without having contact with the external environment, the characteristics of such a system will be different from the training systems assisted by CAI type (Computer Assisted Instruction). Even working manners differ, not necessarily by name, but especially by essence. Computer-assisted instruction systems in Wegener model are non immersive applications for desktop, with interactivity degree at the level of the mouse, joystick, and the more sensitive screen.

So, to those shown, applications with virtual reality techniques fall at least into one Wegener extended model, if not the model itself, to reflect the characteristics mentioned , see Figure 5.

Specific modes of computer training through virtual reality have different characteristics e.g.[10]: tutorial, exercise, educational game, modelling, simulation and solving problems should be adjusted to reflect the specific virtual reality. Also learning activities are different from one style of learning to another and must allow applications meet this requirement e.g.[11].
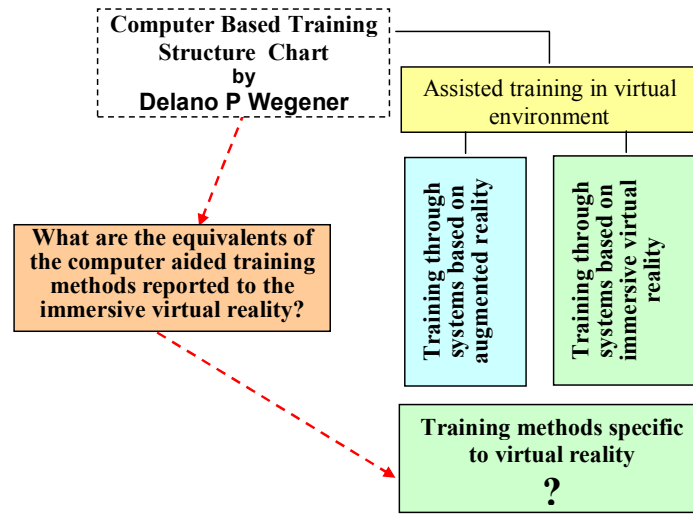

Figure 5: Extended Wegener structure chart.

3. PILOT TRENING STATION USING VIRTUAL REALITY –PARTIAL ACHIEVEMENTS

To introduce virtual reality for training e.g. [11,12,13,14], for the disciplines of applied mechanics of the technological high schools curricula, as a first step, it is proposed a pilot station, corresponding didactic documentation and going through the appropriate steps needed for approval and implementation of this procedure.

The structure of the pilot station consists of an HMD, or for the beginning a pair of stereoscopic glasses, a pair of gloves, CYBER GLOVE, proper interface between them and the virtual environment (VRML), a computing system and corresponding software.

In Figure 6 you can see the CYBER GLOVE and the hand in the virtual setting, interconnected by the corresponding interface.

For a good operating, the software system developed must be capable to synchronize data transmitting to all the computers used for visualization, both those that describe the virtual scene and those related to the user's interaction with virtual environment, leading to an extreme complexity. The software architecture of the system is client / server type based on the separation of the VR events management the following main modules:
- Multi-User Server: manages data related to users connected to the system and produces 3D models management.
- Virtual Environment Server: coordinates local projections and navigation in the virtual environment.
- Cave – Virtual scene Client: manages all the events on how the user interacts with 3D virtual environment.
- Glove Client: allows recognition of user gestures.
- Collision detection: allows collision detection among virtual objects.
ARTTrack Client: enables tracking of user movements.

For communication between client applications in virtual collaborative environment, there are used communication protocols TCP / IP and UDP (User Datagram Protocol). The programming environment chosen is Microsoft Visual C + + which is necessary to integrate information from other software through functions provided by the Microsoft Foundation Class library (MFC). C + + is one of the most popular modern programming languages that supports object oriented programming. These objects are defined by classes. The information contained in the classes is divided into data members and functions members or methods. A class allows encapsulation (information hiding) in it of data and code, prohibiting outside access to data and its functions. To the representation and view of the virtual models in the VRSolid system it has been decided to use the VRSolid language VRML (Virtual Reality Modelling Language) because it is the format the most often encountered in applications of VR, being standardized under ISO / IEC 14772. The use of the VRML format is a viable solution for the information portability of the CAD model and to other CAD or virtual reality systems. Also, the VRML language allows CAD models view in the browser of the Internet, which is an important advantage especially for remote collaboration of members of mixed users' teams.

VRML language is modular, with a hierarchical tree structure of entities, allowing the creation of 3D settings in which the user can move freely, see Figure 7. VRML files are text files that can be created using a text editor and saved in ASCII format with the extension .wrl. For visualisation, specialized programs are used, the most popular being BSContact, Cortona VRML, Cosmo Player. These programs read the file written in VRML language and automatically generate the virtual environment. VRML objects are described in the form of knots, with a mechanism for their nesting.   VRML files must begin with the #

VRML V2.0 utf8 followed by the structure of nested nodes. Below it is presented the structure of a VRML file for a cylinder shape and its tree-like structure, see Figure 7.
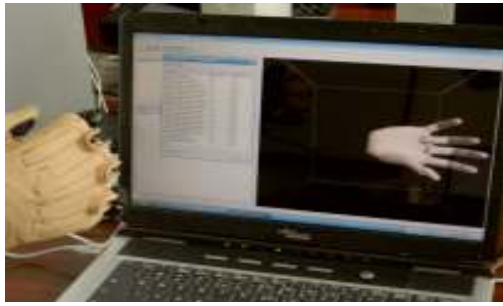

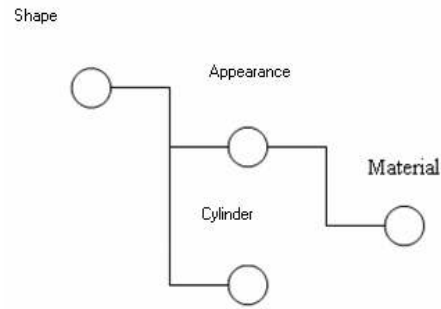**Figure 6:** CYBER GLOVE and virtual hand

Figure 7: Tree – like structure of the VRML file

The major steps taken for handling virtual models. are:
 establishing a database that will contain virtual VRML models;
 stereoscopic display of the virtual environment;
 reading signals from the tracking movement on Udp port;
 citation signals transmitted by CyberGlove glove on port RS232;
 citation signal transmitted by the glove FakeSpace on RS232 port;
 interpreting signals and transmission events to virtual objects;
 update of the virtual environment;
 visualization of virtual environment in the virtual scene or in Holo-Cave system.

For spatial localization of virtual objects it is used a transformation matrix called Mpo, which allows the calculation of position and orientation of a virtual model. The first 3 lines of the matrix define the rotation applied to a virtual environmental object. The first line calculates the orientation of the item around the axis x, the second around the y axis and the third around the axis z. The last line of the matrix allows the calculation of the translation of a model component. The 3 components define the translations along the axes O_x, O_y, O_z.

Experiment

The objective of this experiment is to evaluate the effectiveness of manipulation of virtual models using metaphors of interaction RV, first person in an immersive virtual environment.

For this experiment we have used several virtual objects: a bearing, a parallelepiped, a cube, a screw, a toothed wheel, a spindle, two nuts, 3 boxes for storing items. The objects were placed on a virtual table, see Figure 8. On the table there were represented reference positions for models represented by virtual boxes. The user had to translate and rotate patterns in these positions respectively. Models have been developed using SolidWorks program and imported in VRML format within the software developed.

For assembling a bearing on a shaft in a first stage the user should select the shaft, and then tapping the thumb with the forefinger of the FakeSpace glove will grip that object with the left hand. After gripping through an optical device for movement tracking with six degrees of freedom, the user can manipulate the shaft. In the next stage he will select the bearing and through the CyberGlove will send a gripping command to it. After gripping through the optical device for movement tracking with six degrees of freedom, the user can assemble the bearing on the shaft, see Figure 9. After positioning the bearings, the user will forward a motion to release the bearing and then he will place the outcome on the table by moving his left hand.

Figure 8: Virtual environment used for prehension testing

Figure 9: Virtual anssembling a berring on a shaft

Furthermore, we will improve these applications; we will try to obtain more complex assemblies, attesting the acquisition by students of the objectives of that activity. Also, there are taken into account the adjustments required for training in the disciplines of applied mechanics and of students, and as shown, finally we seek the approval of this learning – training procedure. We can note that currently the identification of the peculiarities of training application using *virtual reality* at the subject "Systems for transmitting movement" of the curricula of technical high schools.

4. CONCLUSIONS

The following conclusions can draw based on those presented in this paper :
- for to stimulate the mechanic systems behaviour a very good method is to obtain geometric modelling of the system components with a CAD software for example SolidWorks, the change of the geometric model through SimMechanics into a dynamic model and through the export of the geometric model to VRML and coupling to the virtual setting, getting quality simulations;
- a viable alternative is the involvement of virtual reality techniques in teaching to the need for equipping the laboratories and workshops where activities in the area of technical disciplines and especially mechanic are performed, given firstly the need for a permanent connection to the requirements of technologies in a constant changing;
- deepening the didactic and psychological implications, and the correlation between objectives, methods and equipment required are imposed as absolutely necessary;
- technical testing procedures and specific methods of using virtual reality in training activities in the disciplines of applied mechanics can be done successfully through a proper pilot station.

REFERENCES

[1]   Binder J: A New Era for Simulation Engineering, AEROSPACE AMERICA, pp. 24-26, January 2007.
[2]   Connection between Professional and Technical Education, University Education and Business Environment – Challenges and Opportunities, National Conference, Sinaia, Romania , 23-24 April 2007.
[3]   Professional Training Standard, Technological High School level 3, Mechatronist Technician, Annex no.2 at OMEdC no.1847 on 29th August 2007, Ministtry of Education, Research and Innovation of Romania.
[4]   Staretu I., C. Dudulean C. : The Use of Virtual Reality in the Training Process Specific to Mechanic Disciplines in the Technical Vocational High Schools Curricula – Methodological Implications, National Conference of Virtual Teaching, Constanta, October 26-28, 2007, pp.109-116.
[5] WG2. 9 partners Education and Training working group, Virtual Reality and learning: requirements for European support, INTUITION- IST-NMP-1-507248-2, 13/01/06.
[6]   Roşca Gh. I., Apostol C., Zamfir G., Bodea C.: Informational Technology for Training, Economic Publishing House, Bucharest, 2002.
[7] Wegener D.P.:CBT Structure Chart , http:// delweg.com/ dpwessay/ cbtchart. gif , 1999.
[8] Muntean Itu A., L. Brad L.: SolidWorks 2000- Lab Work Guide, Publishing House TODESCO, 2001.
[9] Danek J.,Turevskiy A., Denery T.: Simulation and Animation of Mechanical Systems, Proceedings of The AIAA Modeling and Simulation Technologies Conference and Exhibition , Hilton Head, South Carolina, 20-23 August 2007.
[10] Christodoulou S. P., Garyfallidou D. M., Gavala M. N., Ioannidis G. S.,Papatheodorou1 T. S., Stath E. A. : Haptic devices in Virtual Reality used for Education: Designing and Educational Testing of an Innovative System, Proceedings ICL 2005 - Interactive Computer Aided Learning, Villach, Austria, September 28-30, 2005.
[11] Staretu I.: Simulation, Manufacturing and Implementation of a Training Pilot System with Virtual Reality Technologies and Articulate Robotic Structures Dedicated to Technical Disciplines of Applied Mechanics SRIPTMA, National Grant CNCSIS : PN-II-ID-PCE-2008-2.
[12] Impelluso T., Metoyer T.: Virtual Reality and Learning by Design: Tools for Interacting Mechanical Engineering Concepts, Frontiers in Education Conference, 2:F3C/14-F3C/19 vol.2, Kansas City, 18-21 Oct. 2000.
[13] Youngblut C.: Educational uses of virtual reality technology, www.hitl.washington.edu/scivw/youngblut-edvr/D2128.pdf 1998.
[14] Suarez F. J., Alvarez I.:Interactive Educational Visits with Immersive Virtual Reality, Current Developments in Technology - Assisted Education, Published by FORMATEX,Vol. III, pp.1964-1967, Badajoz, Spain, 2006.