The 6th International Conference on Virtual Learning
VIRTUAL LEARNING – VIRTUAL REALITY

Phase II - Period 2010-2020: e-Skills for the 21st Century
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The ICV and CNIV projects supports edivision2020: www.eduvision.ro

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The printing of Proceedings was sponsored by the Ministry of Education, Research, Sports and Youth of Romania, National Authority for Scientific Research, ROMANIA

Proceedings of the 6th International Conference On Virtual Learning

October 28 - October 29, 2011

MODELS & METHODOLOGIES, TECHNOLOGIES, SOFTWARE SOLUTIONS
Phase II - Period 2010-2020: e-Skills for the 21st Century

ICVL 2011
INTERNATIONAL CONFERENCE ON VIRTUAL LEARNING

editura universității din bucurești, 2011

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www.icvl.eu **www.cniv.ro**

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Desktop publishing: Meri Pogonariu

ISSN: 1844-8933

MOTTOS

„The informatics/computer science re-establishes not only the unity between the pure and the applied mathematical sciences, the concrete technique and the concrete mathematics, but also that between the natural sciences, the human being and the society. It restores the concepts of the abstract and the formal and makes peace between arts and science not only in the scientist' conscience, but in their philosophy as well."

Gr. C. Moisil (1906-1973)
Professor at the Faculty of Mathematics, University of Bucharest,
Member of the Romanian Academy,
Computer Pioneer Award of IEEE, 1996
http://www.icvl.eu/2006/grcmoisil

"Learning is evolution of knowledge over time"

Roger E. Bohn
Professor of Management and expert on technology management,
University of California, San Diego, USA,
Graduate School of International Relations and Pacific Studies
http://irps.ucsd.edu/faculty/faculty-directory/roger-e-bohn.htm

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2010 – TOWARDS A LEARNING AND KNOWLEDGE SOCIETY – 2030
VIRTUAL ENVIRONMENTS FOR EDUCATION AND RESEARCH

C^{3}VIP: "Consistency-Competence-Clarity-Vision-Innovation-Performance"

Partners: Ph. D. Prof. Grigore Albeanu, Ph. D. Mircea Dorin Popovici,
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– The Romanian Ministry of Education and Research
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Participate

The Conference is structured such that it will:

- provide a vision of European e-Learning and e-Training policies;
- take stock of the situation existing today;
- work towards developing a forward looking approach.

The Conference will consider the perspectives and vision of the i-2010 programme and how this will stimulate the promotion, and development of e-Learning content, products and services and the contribution of these to lifelong learning.

Participation is invited from researches, teachers, trainers, educational authorities, learners, practitioners, employers, trade unions, and private sector actors and IT industry.

Research papers – Major Topics

The papers describing advances in the theory and practice of Virtual Environments for Education and Training (VEL&T), Virtual Reality (VR), Information and Knowledge Processing (I&KP), as well as practical results and original applications. The education category includes both the use of Web Technologies, Computer Graphics and Virtual Reality Applications, New tools, methods, pedagogy and psychology, Case studies of Web Technologies and Streaming Multimedia Applications in Education, experience in preparation of courseware.

Thematic Areas / Sections

- **MODELS & METHODOLOGIES (M&M)**
- **TECHNOLOGIES (TECH)**
- **SOFTWARE SOLUTIONS (SOFT)**
- **"Intel® Education" – Innovation in Education and Research (IntelEdu)**

Objectives

2010 – Towards a Learning and Knowledge Society – 2030

At the Lisbon European Council in March 2000, Heads of State and Government set an ambitious target for Europe to become **"the most competitive and dynamic knowledge-based economy in the world"** by 2010. They also placed education firmly at the top of the political agenda, calling for education and training systems to be adapted to meet this challenge.

Relevant topics include but are not restricted to:

- National Policies and Strategies on Virtual Learning
- National Projects on Virtual Universities
- International Projects and International Collaboration on Web-based Education
- Dot-com Educational Institutions and their Impact on Traditional Universities
- Educational Portals for education and training
- Reusable Learning Objects for e-Learning and e-Training
- Testing and Assessment Issues of Web-based Education
- Academia/Industry Collaboration on Web-based Training
- Faculty Development on Web-based Education
- Funding Opportunities for Projects in Web-based Education

Learning and the use of Information and Communication Technologies (I&CT) will be examined from a number of complementary perspectives:

- **Education** – supporting the development of key life skills and competences
- **Research** – emerging technologies and new paradigms for learning
- **Social** – improving social inclusion and addressing special learning needs
- **Enterprise** – for growth, employment and meeting the needs of industry
- **Employment** – lifelong learning and improving the quality of jobs
- **Policy** – the link between e-Learning and European / National policy imperatives
- **Institutional** – the reform of Europe's education and training systems and how I&CT can act as catalyst for change
- **Industry** – the changing nature of the market for learning services and the new forms of partnership that are emerging

General Objectives

The implementation of the Information Society Technologies (IST) according to the European Union Framework-Programme (FP7)

- The implementation of the Bologna Conference (1999) directives for the Romanian educational system.
- The development of a Romanian Framework supporting the professional and management initiatives of the educational community.
- The organization of the activities concerning the cooperation between the educational system and the economical companies to find out an adequate distribution of the human resources over the job market.
- To promote and implement the modern ideas for both the initial and continuing education, to promote the team based working, to attract and integrate the young graduates in the Research and Development projects, to promote and implement IT&C for initial and adult education activities.

Particular objectives

The development of Research, projects, and software for E-Learning, Software and Educational Management fields

- To promote and develop scientific research for e-Learning, Educational Software and Virtual Reality
- To create a framework for a large scale introduction of the e-Learning approaches in teaching activity.
- To assist the teaching staff and IT&C professionals in the usage of the modern technologies for teaching both in the initial and adult education.

- To improve the cooperation among students, teachers, pedagogues, psychologists and IT professionals in specification, design, coding, and testing of the educational software.
- To increase the teachers' role and responsibility to design, develop and use of the traditional technologies and IT&C approaches in a complementary fashion, both for initial and adult education.
- To promote and develop information technologies for the teaching, management and training activities.
- To promote and use Educational Software Packages for the initial and adult education.

Thematic Areas/Sections

Models & Methodologies (M&M):

- Innovative Teaching and Learning Technologies
- Web-based Methods and Tools in Traditional, Online Education and Training
- Collaborative E-Learning, E-Pedagogy,
- Design and Development of Online Courseware
- Information and Knowledge Processing
- Knowledge Representation and Ontologism
- Cognitive Modelling and Intelligent systems
- Algorithms and Programming for Modelling

Technologies (TECH):

- Innovative Web-based Teaching and Learning Technologies
- Advanced Distributed Learning (ADL) technologies
- Web, Virtual Reality/AR and mixed technologies
- Web-based Education (WBE), Web-based Training (WBT)
- New technologies for e-Learning, e-Training and e-Skills
- Educational Technology, Web-Lecturing Technology
- Mobile E-Learning, Communication Technology Applications
- Computer Graphics and Computational Geometry
- Intelligent Virtual Environment

Software Solutions (SOFT):

- New software environments for education & training
- Software and management for education
- Virtual Reality Applications in Web-based Education
- Computer Graphics, Web, VR/AR and mixed-based applications for education & training, business, medicine, industry and other sciences
- Multi-agent Technology Applications in WBE and WBT
- Streaming Multimedia Applications in Learning
- Scientific Web-based Laboratories and Virtual Labs
- Software Computing in Virtual Reality and Artificial Intelligence
- Avatars and Intelligent Agents

Topics of interest include but are not limited to:

Virtual Environments for Learning (VEL):

- New technologies for e-Learning, e-Training and e-Skills
- New software environments for education & training
- Web & Virtual Reality technologies
- Educational Technology and Web-Lecturing Technology
- Advanced Distributed Learning (ADL) technologies
- Innovative Web-based Teaching and Learning Technologies
- Software and Management for Education
- Intelligent Virtual Environment

Virtual Reality (VR):

- Computer Graphics and Computational Geometry
- Algorithms and Programming for Modeling
- Web & Virtual Reality-based applications
- Graphics applications for education & training, business, medicine, industry and other sciences
- Scientific Web-based Laboratories and Virtual Labs
- Software Computing in Virtual Reality

Knowledge Processing (KP):

- Information and Knowledge Processing
- Knowledge Representation and Ontologism
- Multi-agent Technology Applications in WBE and WBT
- Streaming Multimedia Applications in Learning
- Mobile E-Learning, Communication Technology Applications
- Cognitive Modelling, Intelligent systems
- New Software Technologies, Avatars and Intelligent Agents
- Software Computing in Artificial Intelligence

Education solution towards 21st Century challenges (IntelEDU):

- Digital Curriculum, collaborative rich-media applications, student software, teacher software
- Improved Learning Methods, interactive and collaborative methods to help teachers incorporate technology into their lesson plans and enable students to learn anytime, anywhere
- Professional Development, readily available training to help teachers acquire the necessary ICT skills
- Connectivity and Technology, group projects and improve communication among teachers, students, parents and administrators

Workshop

Haptic Feedback Systems in Education

This workshop will be devoted to developments and issues involving haptic systems in education. Topics will range from haptics in human computer interaction to haptic applications in medical training

- Haptics is the science of merging tactile sensation with computer applications, thereby enabling users to receive feedback they can feel (in addition to auditory and visual cues). Multimodal environments where visual, auditory and haptic stimuli are present convey information more efficiently since the user manipulates and experiences the environment through multiple sensory channels
- The availability of haptic systems enables the augmentation of traditional instruction with interactive interfaces offering enhanced motivation and intellectual stimulation. Although the haptic devices have not made large inroads into education, we believe that the potential for revolutionary change now exists due to the recent availability of both the hardware and software component

SenseGraphics - Medical Simulators Built on H3DAPI

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Abstract

H3D API, SenseGraphics flagship product, is a dual commercial and GPL (open source) licensed software that has been recognized by many in the haptics industry as an ideal development platform for multi-sensory applications. H3D API uses the open standards X3D and OpenGL, and leverages on a diverse range of haptics platforms and technology including those of SenseAble, Novint and ForceDimension. We also offer professional haptic training, support and consulting services, as well as custom hardware solutions..

Keywords: haptics, medical simulators

1. Introduction

SenseGraphics' vision is to facilitate application development of haptic, and co-located hapto-visual, applications. Founded in 2004 in Stockholm, SenseGraphics represents over twenty years of experience in the haptics and graphics industry. Our company provides a high performance application development platform which enables integration of haptics and 3D stereo visualization into multimodal software applications. Our development platform consists of two main components, hardware and software solutions, offering the complete set of technologies needed to initiate 3D or haptics application development.

H3D API, SenseGraphics flagship product, is a dual commercial and GPL (open source) licensed software that has been recognized by many in the haptics industry as an ideal development platform for multi-sensory applications. H3D API uses the open standards X3D and OpenGL, and leverages on a diverse range of haptics platforms and technology including those of SenseAble, Novint and ForceDimension. We also offer professional haptic training, support and consulting services, as well as custom hardware solutions.

2. Our Technology

While it promises many exciting possibilities, haptics development and research are still costly practices, in part due to the sophistication of haptic hardware and in another, due to proprietary haptics software. Our open source haptics and 3D stereo technology seek to minimize these expenses, thereby promoting development of haptic applications.

Our technology comprises: haptics development platforms and hardware.

2.1. Haptics Development Platforms

H3D API

The brainchild of SenseGraphics, H3D API is fast becoming the standard for high performance haptics application development. This open source, hardware independent platform is designed for anyone interested in building haptics applications from scratch. The H3D API uses the open standards X3D, OpenGL and SenseGraphics haptics. It offers a unified scenegraph which simplifies haptic and graphic rendering.

The big plus point that H3D API offers users is the ease with which haptic applications can be built. It is possible without extensive programming experience to build haptics applications using solely H3D (which extends from X3D) or with the scripting language Python. Additionally, C++ programming may be used in H3D API for any advanced developments. As H3D API is open source and released under the GNU General Public License, users are free to modify and extend it as needed.

The H3D API has been used widely by many research and academic institutions including the Royal Institute of Technology (KTH) and Norrköping Visualization and Integration Studio in Sweden, Cork University Hospital and University of Wales, Bangor in the United Kingdom, and Iowa State University and Armstrong Atlantic State University in the United States.

HAPI

HAPI is the new haptics rendering engine by SenseGraphics which supports a variety of haptics devices including those from SenseAble, ForceDimension and Novint. With HAPI, users are now able to choose between four rendering algorithms. It's modular design also meant that users are able to add rendering algorithms of their own.

While H3D offers quick creation of new haptics applications, HAPI allows users to add haptics to existing applications. The choice rests with the users whether to complement HAPI with H3D API, or with other graphics platforms, including but not limited to OpenGL and DirectX.

HAPI is written in C++ and like H3D API, HAPI is open source.

2.2 Haptic Hardware

Our technology also encompasses the hardware settings in a haptics system. We provide haptics interfaces, and build fully immersive 3D stereo systems with co-location of haptics and graphics.

Both our immersive hardware and H3D API have been applied in various projects, including the haptic stroke rehabilitation system by Curictus AB.

3. Medical simulators

SenseGraphics is helping companies bringing their products to the market in a fast and cost effective way. Below you will find examples on products for the dental and medical industry where SenseGraphics has been a successful technology provider and application development partner.

3.1. MOOG Simodont Dental Trainer

MOOG is a worldwide designer, manufacturer and integrator of precision motion control products and system. The Simodont Dental Trainer (fig. 1.a) is a high quality, high fidelity simulator allowing for future dentists to be trained in operative dental procedures in a realistic dedicated virtual environment while receiving haptics, visual and audio sensory information.

SenseGraphics has been part of the development team of the MOOG Simodont Trainer, providing both haptics and 3D visual functionality to the simulator. The first 50 units of the Simodont Dental trainer was installed in the new ACTA Dental School building in August 2010. ACTA, who aslo funded the development of the Simodont trainer, is a world-class dental educator based in the Netherlands.

The main features of Simodont trainer are the advanced control technology by a unique admittance control paradigm using a force sensor for high fidelity feel; a flexible software interface by providing maximum flexibility in creating new applications; and strong reliability by proven technology and patented control algorithm that allow the full spectrum of movement from very high to very delicate forces.

At any given moment, in training centers around the world, a Moog simulation solution is always at work providing an unsurpassed level of performance, fidelity and reliability.

a) b)

Figure 1. **a) Simodont dental trainer setup, b) ScanTrainer in practice**

The dental trainer provides high-end dental simulation and training. It is a complete, proven training system for dental schools committed to helping students progress faster and professors track progress and plan student work efficiently.

Simodont® Courseware is developed by (ACTA) Academic Center for Dentistry, Amsterdam, the Netherlands.

3.2. MedaPhor ScanTrainer

MedaPhor is one of the UK's leading ultrasound training companies. The Medaphor ScanTrainer (fig. 1.b) is an ultrasound training simulator which provides effective ultrasound training, independent of a clinical setting, using a virtual environment with the feel of a real procedure.

The ScanTrainer was brought to the market in 2010, built on H3DAPI and with haptics expertise from the SenseGraphics software development team. Conclusion

ScanTrainer provides sophisticated ultrasound learning in a non-clinical environment without any impact on clinical service delivery, solving the current resource conflict between provision of clinical service and need to train. It also helps overcome the current shortage of learning capacity in hospitals and training centers.

The structured ScanTrainer learning environment, with tutorials, assignments, tasks and metrics, ensures an effective and reproducible training program with reduced impact on clinical services and reduced expert supervision.

Moreover, it improves the quality and breadth of ultrasound learning prior to the trainee's exposure to patients by offering self-directed learning with feedback means that the system can be used without an expert's direct supervision, and is thus highly cost-effective.

3.3. The Haystack Project

A hapto-visual simulator for training in and assessment of performance of Ultrasound guided Peripheral Nerve Block (USgPNB). Built on H3DAPI, and with SenseGraphics haptics expertise, the Haystack is a collaboration by NDRC (National Digital Research Centre), the HSE (Cork University Hospital Department of Anaesthesia), and MedaPhor Ltd.

4. Conclusions

The potential of haptic interfaces in support of practice based learning in medical training is tremendous. More, it starts to be proven in many domains, even in rehabilitation, due to the capability of H3DAPI force feedback haptic technology to create a realistic environment for the patient, enhancing the training experience and facilitating the relearning processes.

References

SenseGraphics, http://www.sensegraphics.com/index.php

An approach for teaching mechanisms using haptic systems

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Abstract

This paper presents a methodology and a prototype system for teaching mechanisms in mechanical engineering courses, by using haptic devices. The paper begins with the presentation of an experimental study on using generic haptic devices for simulation of mechanism. Based on the results of the conducted study a custom haptic system with 1 DOF was developed. Afterwards it is presented the proposed methodology, which integrates the haptic device developed for the specific case of articulated mechanisms. In order to increase the realism of the simulation, the virtual mechanism model is co-located with the user's real hand using augmented reality techniques and see-through featured head mounted display. Therefore, the mechanical system used for the experiments is composed of one or more real and virtual elements and joints (for example a crank linked to a torque controlled electrical motor). The software, hardware and methodology, as well as the results are described in detail. The advantage of this system is the use of inexpensive haptic equipment for intuitive learning of the simulation of mechanisms.

Keywords: Haptics, Augmented Reality, Mechanism, Teaching methodology

1. Introduction

An undergraduate mechanical engineering curriculum invariably includes a course about the Theory of Mechanisms and Machines through which students learn modelling and analysis of mechanisms. Teaching Theory of Mechanisms and Machines has traditionally relied on physical models. These physical models provide an intuitive representation of the mechanical structure, allowing students to explore aspects such as type and construction of joints, mobility etc. The classical teaching method is a difficult task, which requires students' imagination or use of expensive mechanical installations. Moreover, it seems that it is not well understood by the students because they are more interested in other interdisciplinary fields related to this topic, e.g. robotics and mechatronics.

Recent advances in Computer Aided Design (CAD) and Engineering (CAD/CAE) have allowed creation of virtual prototypes that represent mechanical systems at any scale and complexity. By using CAD/CAE systems for virtual prototyping, the user has to be a skilful engineer because these systems only allow the visualisation of the simulation results as 2D drawings, plots or graphs and require a mental transformation of 2-D objects into dynamic 3-D objects, which is a difficult process for an undergraduate student.

Virtual Reality technologies facilitate the development of new industrial applications by providing advanced visualization capabilities and multi-sensorial human interaction interfaces.

Positive results where reported by applying VR technologies to automotive engineering, aerospace engineering, medical engineering, and in the fields of education and entertainment (Craig et al., 2009).

Recently, haptic interface has been proposed as an ideal interface for teaching systems dynamics to mechanical engineering undergraduate students (Butnariu and Talaba, 2010; Duma, 2010; Gillespie et al., 2003; Okamura et al., 2002, Wiebe et al., 2009). Using haptic systems, the numerical results of simulations and tests can be converted into forces that the user can percept. This way the plots and graphs can be replaced with the actual experience of switching a virtual device reproducing the force feedback that would characterize the real counterpart with a high degree of fidelity (Erdelyi and Talaba, 2010).

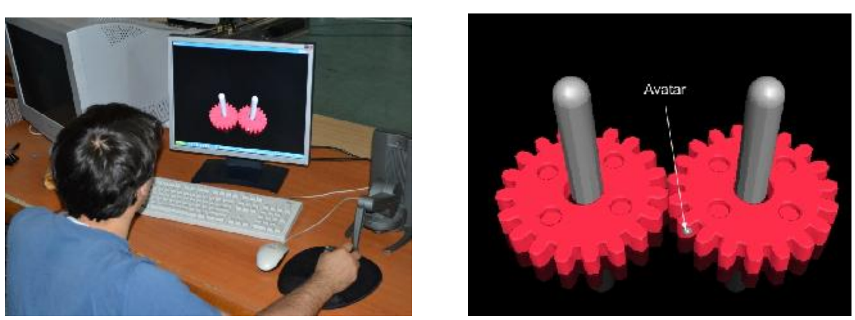
This paper presents a methodology and a haptic prototype system for teaching mechanisms in mechanical engineering courses. This method to achieve such results consists of augmented reality technologies (Azuma, 1997) used to co-locate computational (virtual) models with the real physical models and haptic feedback to provide additional information about the augmented models. Using this teaching concept, a variety of computational mechanism models can be studied, which reduces the need for classical experiment involving expensive installations.

2. Experimental study on using generic haptic devices for simulation of mechanism

Before introducing the haptic devices in the mechanism teaching process, we conduct an evaluation study for the generic haptic devices (like Sensable PHANTOM). The objective of this evaluation study is to assess the efficiency and the usability of generic haptic devices for interaction/manipulation of mechanism in virtual environment. The study was performed considering the case of manipulation of a gear mechanism in a virtual environment (fig. 1b).

The interaction between the real object (haptic device) and the virtual mechanism is achieved through an "avatar" - graphical representation of the haptic device implemented in the virtual environment (fig. 1b). The avatar handling is done by using a Sensable PHANTOM haptic device and the perception of the virtual environment is done trough a "desktop" virtual reality system (fig. 1a). The user manipulates the haptic avatar through the Phantom device, interacting with virtual mechanism. When a collision with the virtual gear is detected, the equipment returns the corresponding haptic feedback. The force feedback is calculated according to the collision between the avatar and the virtual mechanism. For this experiment a haptic library called Chai 3D (www.chai3d.org) has been used, which incorporates algorithms used to detect collisions between virtual objects and the Open Dynamics Engine (www.ode.org) applied for dynamics simulation of multibody systems.

Five subjects with mechanical background participated at this experiment. After conducting the experiment, we can conclude that the interaction with a virtual mechanism is particularly difficult using such a haptic device because of the punctual virtual contact.



a) b)

Figure 1. **Interaction with PHANToM device (a) haptic avatar and mechanism (b)**

In order to manipulate the mechanism and to feel the forces that appear in the system, the user has to push one of the gears. This process has proven to be difficult, because the avatar is not fixed on the gear and it can move freely on its surface, meaning the loss of contact with the mechanism in a very short time.

The usability of generic haptic devices is limited to applications based on the punctual virtual contact. Thus, we have decided to develop and use custom haptic devices dedicated to simulation of mechanisms. In the next section is presented the design and development of haptic systems with one degree of freedom dedicated to simulation of mechanisms.

3. The development of the dedicated 1 DOF haptic interface for simulation of mechanisms

The virtual simulated mechanism is connected to a real system consisting of a DC brushless motor and a real crank. The motor is controlled by a special controller which communicates with a computer trough an RS232 interface. In this controller are implemented some control functions, like: proportional derivative (PD) element which assesses the speed mode, proportional integrative (PI) feature used for controlling the motor in current mode and proportional integrative-derivative (PID) for control motor in position mode. Movement of the real crank is measured by using an optical encoder assembled in the motor. The data provided by this sensor is converted in angle and used as input for the simulation of the mechanisms. A schematic diagram of the complete system is presented in figure 2 where “1” represents the DC brushless motor equipped with a real crank element, “2” represents the computer that runs the simulation and “3” is Trivisio HMD device used for visualization of the simulation. The motor is controlled in current mode because the force provided from simulation is directly proportional with the current applied to the motor. To increase force to the user hand, a planetary gearbox with ratio 150:1 is mounted at the output of the motor. The refresh rate of displayed force at the human hand level is approximate 300Hz because of the speed limitation of the serial port RS232.. Baud rate for read/write to motor controller is 115200 bauds. We test this interface with multiple users and interaction was very realistic, all users feel mechanism manipulation like real one.

For good immersion of the user, augmented reality (AR) techniques are used to render the virtual crank over imposed to a video string achieved by a video camera mounted at the user’s head level. Using these techniques, position and orientation of a custom marker is detected in the real environment using image processing algorithms. The marker data must be stored in a file on computer and compared to the data processed in the video string. Position and orientation of the marker is used as input for render engine. Users can view the mechanism over imposed in the real environment using a Head Mounted Display (HMD) (fig. 2b). An HMD is a display device mounted to the user head that display images using two little Liquid Crystal Display (LCD). At Transylvania University from Brasov, we have a Trivisio HMD with two video cameras on it and users can view stereoscopic images over imposed to the video stream.

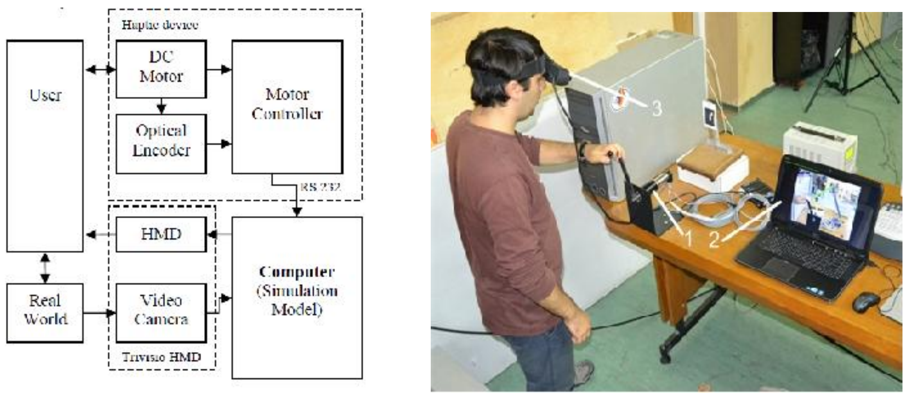
4. Methodology and results

The course that we are reporting on this paper is delivered during one semester (14 weeks, 4 hours a week). In the laboratory, students complete a project wherein they implement a simulation of an articulated mechanism with haptic feedback. During the first weeks of the semester, each student has received a different articulated mechanism with following input parameters: construction, geometry, masses and operating characteristics. The methodology followed by the student to complete the assigned project involves the next steps:

(1) Generating the virtual 3D model of the mechanism - using specialized Computer Aided Design software (for example Solidworks).

(2) (2) Conversion of the 3D model mechanism data. The virtual model cannot be loaded in the AR software because there is not standard interoperability procedure. Therefore this step

consists in extracting the entire geometric data of the CAD model and conversion of standard CAD file to an appropriate common exchange file format (for example 3ds, VRML, X3D etc.) that can be loaded by general AR dedicated framework.



a) b)

Figure 2. **1 DOF haptic system architecture (a) components of the haptic system (b)**

(3) Integration of the virtual mechanism model in AR software. Consists in the configuration file generation that contains the marker tracking setup and the 3D scene file.

(4) Generation of a unique marker. Consists in generation of a unique fiducial marker for each 3D CAD model and storage the marker shape data in the AR software.

(5) Registration of the co-located virtual mechanism model. This step involves modification of scale, 3D position, and orientation, relative to the camera transformation matrix by using the keyboard.

(6) Development of the mechanism kinematics and dynamics model. For the calculation of forces and movements of virtual mechanism classical multi-body systems dynamics formalism was used. The rigid elements of mechanism are interconnected through joints. On some elements of the mechanism, there are applied forces (springs, dampers) in order to achieve haptic effects. The equations of motion are:

[1]
$$
\begin{aligned}
M(q)\ddot{q}(t) &= f(t,q,\dot{q},\lambda) - G^T(t,q)\lambda, \\
0 &= g(t,q),
\end{aligned}
$$

Where: q- coordinates of bodies; $M(q)$ - generalized mass matrix; f - vector of applied forces. The joints decrease the number of degrees of freedom in the system, generating constraints, which are introduced in dynamics mathematical equations through the GT forces (t, q) = (∂ g / ∂ q) (t, q) using Lagrange multiplier λ.

(7) Calculate the force feedback. Consist on conversion of calculated forces from dynamic model of the mechanisms to level of current to be applied to the motor.

To demonstrate the methodology presented above we present a project where this was applied for a slider-crank type mechanism (fig. 3).

The slider-crank type mechanism is composed of two rigid bodies and three articulations and has only one degree of freedom:

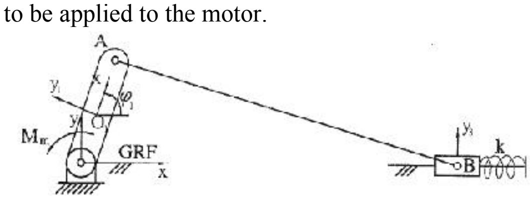


Figure 3. **Schematic representation of slider-crank mechanism with dynamic elements**

[2] $L = 3n_c - \sum r_i = 6 - 5 = 1$

To move this mechanism we need to know only crank angle φ1. In order to solve the problem, they will follow the steps outlined in presented methodology. First, the students analyze the mechanism in order to establish the components, their position and the couplings between them. Then, a 3D model of the mechanism needs to be created, using dedicated software studied in other classes (e.g. CATIA CAD software).

The 3D CAD model is composed from separate parts corresponding to the components of the mechanism. Each component of the mechanism is modelled as a distinct CAD part, and then all of the parts are assembled in their position. The 3D model can not be used in native CATIA format because of lack of interoperability between AR and CAD systems. The CAD system can export the CAD graphical models in other formats (for example Virtual Reality Modelling Language). Therefore, the VRML language is used for the representation of the 3D virtual mechanism it. Using the conversion function directly from the CATIA software will not maintain all the data of the original assembled model. Important features of the CAD model are not transmitted, such as topology of parts. Therefore, the geometrical parts of the mechanism are suitable to be used for visualization, but not for interaction. Consequently it is necessary to export each part individually by activation of the "hide" command in order to conceal other components different from one selected. The result is a VRML file, which contains each entity of the CAD models treated as an individual object.

Software architecture was created for the visualization of the mechanism simulation in a co-located environment. The software architecture is discomposed in an AR co-location software module, an interaction haptic device module, a module for simulation of virtual mechanism and a module for generation of haptic feedback.

The AR software module allows identification of the square marker, determines 3D position and orientation of identified markers in order to align the virtual mechanism onto the real environment and simulates the movement commands of the mechanism.

The code written for the AR software module is based on an open source library called Instant Player (www.instantreality.org). The advantage of using this library is the possibility to integrate various VRML and X3d graphical formats of virtual objects and possibility to create External Authoring Interface (EAI) to transmit data from other C++ or .NET standalone applications using Ethernet.

With the purpose of registration of virtual mechanism model onto the real environment and co-located with the haptic device, a unique square marker was generated and attached in the real workspace. Each marker in the system has a black border and a unique symbol inside the black frame. The Instant Player framework uses the unique symbol to identify the markers. Before using a marker within this framework, the marker's shape data has to be specified through an .xml file. The Instant Player includes computer vision functions that allow analyzing each video frame and identifying markers. In this way, Instant Player gets the camera transformation matrix as well as the marker's id. The 3D position and orientation are used to overlay virtual objects in the real environment. The user can modify scale, 3D position and orientation relative to the camera transformation matrix by using the keyboard. In this way, the registration of the virtual mechanism onto the real environment and co-location with the haptic device (fig. 4) can be adjusted.

In the next step, the kinematics and dynamics calculation was made using analytical methods presented during the course. We do not propose to discuss in this paper about inverse dynamic model of the mechanism. Information about this calculation can be found in (Talaba and Antonya, 2006). After validation of the models, the students will implement a subroutine using C++ programming language. The outputs of the program are the forces from the spring used for generation of haptic feedback and the positions of the mechanism elements used to update the visual representation of the mechanism.

Each student works individually on a computer to generate CAD models, VRML files and C++ simulation programs. After finishing these steps, for the haptic feedback generation and visualization of the simulation in the co-located environment, depending on mechanism characteristics, the students use the presented experimental haptic device where they can interact with virtual simulated slider-crank mechanism. Any change to the input data will lead to changes in kinematics or dynamics features of the studied mechanism.

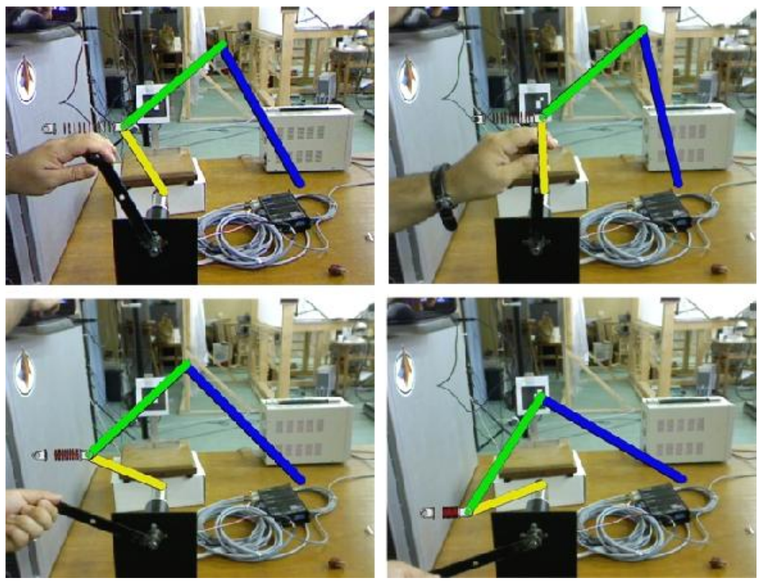


Figure 4. **Student testing a virtual mechanism with the proposed system**

In doing this project, students learn (i) generic concepts of virtual prototyping (ii) specific features of interfacing a motor to a PC, (iii) generic concepts of mechanism simulation (iv) generic concepts of VR and AR, and (v) had a lot of fun programming and experimenting with interesting virtual worlds.

5. Conclusions

In this paper was presented a methodology to study kinematics and dynamics of mechanisms that includes all steps from design to conversion of a CAD model into a VRML virtual scene in order to obtain both quality simulations and haptic feedback delivered to the user in a very similar manner as in a real experiment.

This methodology can be applied to students of the Mechatronics and Robotics departments, assuming knowledge of CAD and programming. This approach proved to be a powerful tool that offers important advantages to the classic teaching methods.

The haptic device can be used only for mechanisms with mobility M=1. In the future, we intend to use this type of interface to make simulators of mechanical machine like manual drilling machine for educational purpose and training. Vibration forces that appear at contact with different materials and different drill speed will be simulated and applied to the motor.

Acknowledgements

The second author's work was supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU 89/1.5/S/59323.

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