SIMULATION AND HAPTIC-ENABLED FRAMEWORKS FOR VIRTUAL LEARNING ENVIRONMENTS

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Abstract

The ability to interact with synthetic entities as if they were real has been the ultimate quest of virtual reality (VR) researchers for decades. Recent advances in virtual environments allow users to see virtual objects and avatars, to hear them, to move them, and to touch them. The direct physical interaction with computer-generated objects enabled by haptic interfaces provides a useful and intuitive augmentation to visual display and the opportunity to enhance the level of understanding of, and interactivity with, complex data sets. These emergent technologies require a new generation of learners, very different in terms of skills and attitudes, demanding the implementation of radical changes. This paper considers the enhancement of a web-based knowledge-driven decision support system designed for implementation in clinical learning settings. The authors explore the use of virtual reality training solutions in practice-based learning and skill rehearsal in medical and clinical situations to create life like simulations.

Keywords: *knowledge management, multimodal interface, haptic technology.*
ACM classification: K.3.1, H.5.2

1. Introduction

Human interfacing with the environment and with other humans is undoubtedly, fully multimodal. All human senses participate to the everyday human operations of perception, action and interaction. Interaction with computer or computer-mediated interaction with others has been based for decades on a limited set of modalities and customised devices. Recent technological advancement in the area of human-computer interaction and haptic technology has made multimodal interfaces a reality.

These advancements of information technology have made a significant impact in the areas of teaching and training and have generated a cultural shift in focus, in transforming learning from passive listening to discovery-based experiential and example-based learning; intelligence organized in easily accessible databases; and community of practice emerging from sharing tasks involving both tacit and explicit knowledge over a substantial period of time.

This paper builds on the development settings of MEDIS, a prototype of a web-based knowledge-driven decision support system designed for implementation in clinical settings. The system developers have envisioned a framework where teachers and students can interconnect, under security restrictions, to a practice-based environment where physicians activate and thus access clinical cases and simulate real-life decisions.

Even if MEDIS allows learners to access knowledge databases that capture the real-time experiences of physicians, their learning experience is far from being complete. There is still a gap in terms of clinical practice that hiders the learner' performance.

Under these premises, the authors analyse the development potential of MEDIS under the impact of emergent technologies that supplement teaching and learning methods and explore the use of virtual reality training solutions in practice-based learning and skill rehearsal in medical and clinical situations. They consider the use of haptic technologies in education and how educators might use haptic technology to augment the sense of presence that a student perceive while working in virtual worlds or on a digital assignment.

2. **Challenges and opportunities in learning environments**

Educators who facilitate learning for students in the health professions are faced with even more increased challenges to promote deep and applied learning required for providing patient care in today's complex health care settings (Kheddar, 2008; Plaisier).

Health professions educators have to prepare a health care workforce that is able to synthesize, communicate with patients, use decision support tools, and provide safe patient care. The challenge of guiding student learning is made more difficult by increasing bodies of knowledge, textbooks full of rapidly out-dated information, and access to Internet-based sources easily retrieved, but less easily critiqued (Ball et al., 2004). While content will continue to be the foundation of educational programs, educators now also must create opportunities for students to develop skills in acquiring, synthesizing, and using information to make enhanced clinical decisions for their patients (Berner and La Lande, 2006).

Recent trends related both to higher education and healthcare delivery systems have created an environment of change for medical education. Driven by the need to address patient safety concerns and improve quality of care, increased technology with which to deliver health care, higher patient acuity and, in some cases, less funding for clinical sites, teachers and physicians must determine alternative and creative ways to teach future medical personnel.

One solution to the growing concerns linked to these trends is the advent of health care simulation in education programs and in hospitals. These simulations, which serve as adjuncts to didactic learning, represent the closest possible technology to real patients and allow for a repetitive "hands-on" learning in a safe environment where mistakes can be safely made. The students who participate in simulations gain experience and confidence on their ability to make critical clinical decisions in acute care situations, where time and skill often have critical consequences.

The practice of medicine has always relied on visualizations. These visualizations either have been direct or have required extensive mental reconstruction, as in the microscopic examination of serial histologic sections. The revolutionary capabilities of new three-dimensional (3D) and four-dimensional (4D) imagining modalities underscore the vital importance of spatial visualization to this science (Knottnerus et al., 2008).

The use of virtual reality (VR) technology opens new realms in the teaching and practice of medicine by allowing the visualizations to be manipulated with intuitive immediacy similar to that of real objects; by allowing the objects to be dynamic, either in response to viewer actions or to illustrate normal or abnormal motion; and by engaging other sense, such as touch and hearing to enrich the visualization (Kortum, 2008). Medical application can include basic anatomy instruction, surgical simulation for instruction, visualization for diagnosis, and surgical simulation for treatment planning and rehearsal (Brewster, S. and Murray-Smith, 2009).

Although the greatest potential for revolutionary innovation in the teaching and practice of medicine lies in dynamic, fully immersive, multi-sensory fusion of real and virtual information data streams, this technology is still under development and not yet generally applicable to the medical researcher. The authors consider a step-by-step development that integrates such innovative approaches.

3. **Practice-Based Medical Education**

With the increased focus on the prevention of medical errors (Berner et al, 2006), Clinical Decision Support Systems (CDSS) have the potential to change the way medicine has been taught and practiced (Greenes et al; 2006; Pol et al, 2009). CDSS have been shown to improve the patient outcomes, the cost of care (Linwood et al, 2006; Inmon et al, 2007; Filip, 2008), as well as the performance of clinical physicians (Stănescu and Ştefan, 2010).

MEDIS is a prototype of a clinical decision support system developed to explore the potential of computer assisted decision making in clinical environments. The system addresses the challenge of providing real-time support and feedback (Berthold and Hand, 2007) to clinical decision-makers and its main objectives are to support knowledge acquisition and reuse, and to foster optimal problem-solving, decision-making and action in the clinical environment.

The system can be accessed from desktop and mobile environments to obtain real-time information and knowledge concerning patients, diseases and treatments. It comprises treatment options, customised for each patient based on his medical record. For example, if a doctor prescribes a treatment that includes incompatibilities with the patient records, the systems automatically signals the problem, reducing the number of medical errors and improving the medication.

The system can be accessed on handheld devices, such as PDAs, XDAs and smart phones. This in-creases accessibility and provides support for decision making in ambulatory environments (Whitten et al., 2005; Lumsden, 2008). Thus, the system provides real-time assistance anytime, anywhere and constitutes an innovative approach to CDSS (Stănescu et al., 2009). In order to facilitate quick access to patient information in emergency situations, the system allows access to the patient's medical records by scanning a two dimensional barcode printed on the patient's health card.

The efficiency of MEDIS depends not only on the performance of software and hardware equipment, but also on the ability of its users to make full use of its functionalities. Based on this premises, MEDIS promotes an innovative approach that facilitates the interconnection between the clinical practice environment and medical education actors that can prepare future generations of medical personnel to integrate CDSS in their daily activity. Students and teachers can directly access, based on privacy and security restrictions, the knowledge database of MEDIS, they can interact with physicians and have access to their comments and recommendations. The connection to this practice based environment increases student performance and generates potential for interconnections with other media.

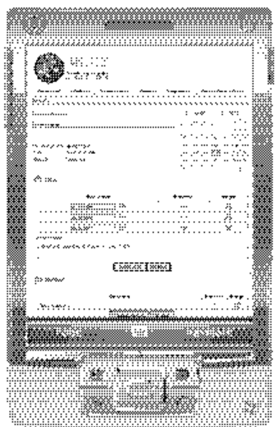

Figure 1. *The mobile interface of MEDIS*

Figure 2. *2D barcodes for quick and secure authentication*

4. Research on haptic enabled learning

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). The term haptic (from the Greek *haptesthai*, meaning "to touch") is the adjective used to describe something relating to or based on the sense of touch. Haptic is to touching as visual is to seeing and as auditory is to hearing. Touch is one of the key sensory channels and it can be divided into cutaneous, kinaesthetic, and haptic systems based on the underlying neural inputs. The cutaneous system employs receptors embedded in the skin, while the kinaesthetic system employs receptors located in muscles, tendons, and joints. The haptic sensory system employs both cutaneous and kinaesthetic receptors, but it differs in the sense that it is associated with an active body motion. For example, cutaneous touch becomes active when the user explores a surface or grasps an object, while kinaesthetic receptors become active when the user manipulates an object and touch other objects with it.

Practitioners and researchers have carried out studies to analyse the effect of haptic feedback on collaborative task performance (Kortum, 2008; Brewster and Murray-Smith, 2009; Hamza-Lup, Lambeth, & LaPlant, 2009; Hamza-Lup and Stănescu, 2009). Simulations have changed the way medicine was taught by improving students' and physicians' performance. For example, traditionally, students learn new techniques in surgery by observing procedures performed by experienced surgeons, and they have to go through an extensive and lengthy training procedure (Knottnerus et al., 2008). However, surgical simulators provide an environment for the future physician to practice many times before operating on a patient. In addition, virtual reality technologies allow the student in training to learn the details of surgery by providing both visual and tactile feedback to the surgeon working on a computer-generated model of the organs of the human body

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 (Hamza-Lup and Stănescu, 2009). Based on the fact that the use of multimodal environments in learning practice improves the student performance, the authors have considered the integration of haptic technologies within MEDIS with the purpose of extending the potential benefits this system can bring to its users and to enhance the learning experience.

One of the concepts that the authors have analysed as a potential beneficiary of the haptic paradigm concerned friction. The students learning about friction can be confused both by its mathematical description and by its nature as a force. The studies conducted showed that the traditional approach presented a few limitations concerning the consistency and the customization of the experiment, and also the user control over a continuous (large) range of physical parameters.

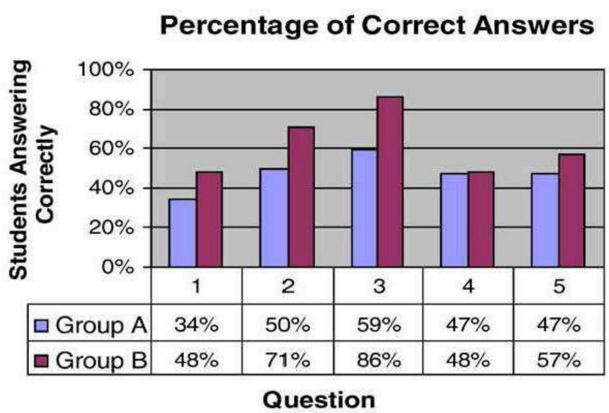

Figure 3. *Test results (group A – no haptic; group B – with haptic)*

Motivated by these limitations the researchers have designed and implemented an environment that simulates the force of friction and the associated paradigms. Students use the haptic device to manipulate a cube on an inclined plane and receive force feedback from the device (Figure 4).

Students may apply varying amounts of force and directly receive varying resultant forces from the cube. They can also change the values that affect frictional force, such as the mass of the cube, the coefficients of static and kinetic friction, and the slope of the plane along which the cube moves. The visuo-haptic simulation provides additional benefits, such as:

• *Affordability*. Low-cost haptic devices that are connected to the existing computers in the school laboratories.

• *Portability*. The students can preview simulations online as part of a distance education tool, or in preparation for the lab.

• *Easy concept understanding*. Force vectors and their attributes can be visualized as 3D arrows. Such forces cannot be visualized in the traditional approach.

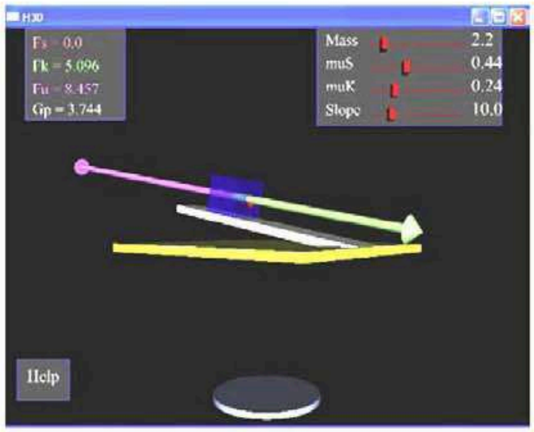

Figure 4. *Users perceive the forces (direction and magnitude) while pushing the cube*

This study reveals the potential that haptic technologies present and how haptic feedback can enhance the learning process, opening the way to the development of new functionalities of MEDIS as a collaborative environment for clinical learning and practice.

5. **Conclusions**

With new scalable learning techniques education reform is possible. As simulations are explored, educational and training organizations will finally be able to do what they want - and need – to do. Simulations can directly add valuable knowledge to the learners' experience. They can teach to tap so much more of students' capabilities. The transformation in experience will be as rich as dramatic as going from watching black and white movies to watching colour movies. This paper underlines the kind of change necessary for universities and organisations to change their view of e-learning and presents a clinical decision support system that facilitate the real-time interconnection between physicians and students as a way forward in medical education. The authors approach the impact of haptic technologies on the educational process and present a case study on how the haptic paradigm can enhance student learning.

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