HAPTIC FEEDBACK SYSTEMS IN EDUCATION

Dorin-Mircea Popovici, Felix G. Hamza-Lup
Department of Mathematics and Computer Science, OVIDIUS University of Constanta, 124 Mamaia Bd., 900537, Constanta, Romania
dm.popovici@univ-ovidius.ro, fham76@gmail.com

Crenguta M. Bogdan
Department of Mathematics and Computer Science, OVIDIUS University of Constanta, 124 Mamaia Bd., 900537, Constanta, Romania
cbogdan@univ-ovidius.ro

Abstract: This paper brings into discussion some of the most relevant technological issues involving haptic systems in education. One of these issues is choosing the suitable haptic hardware, API or framework for developing a visuo-haptic e-Learning system. The decision is based on several criteria such as multimodal resources needed by the software system, compatibility with haptic devices, dynamic configuration of the scene, and so on. Another issue is related to the software system reactivity at the user actions. The immediate haptic feedback from virtual models, together with the synchronisation of haptic and visual cues generated by computer to its users are essential for enhancing the user’s learning path. Such models help to obtain accurate training scenarios developed for the teaching, for example, of medical protocols, or chemical or physical processes.

Keywords: haptic feedback, education, training, virtual environment

I. CHAPTER I - INTRODUCTION

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 components.

II. CHAPTER II – SUCCES STORIES ON USING HAPTICS IN EDUCATION

The potential of haptic interfaces was initially proved in various medical training applications like cardiology [1], prostate cancer diagnosis [2], injection [3] and lumbar punctures procedures [4], surgery [5,6] and angioplasty interventions[7], rhinoscopy and bronchoscopy procedures [8], palpatory diagnosis [9], but also in orthopedic drilling [10] and bone surgery procedures [11]. In[3], the use of haptic device is studied in a combination with speech input and output as interaction means that supplementary triggers emotion at the level of a virtual patient.

Dentistry procedures (as implants [12] or dental preparations [13]) are usually trained using mixed realities (VR/AR) in combination with haptic feedback. The system proposed by [14,15] allows
students to practice surgery in the correct postures as in the actual environment by mixing 3D tooth and tool models upon the real-world view and displaying the result through a video see-through head mounted display (HMD). Their system addresses different student skills levels by incorporating an adaptable kinematic feedback and hand guidance using haptic device, by comparison with an expert gestures.

Guidance is also used in palpatory systems as Virtual Haptic Back Project at Ohio University that implements a haptic playback system using the PHANToM haptic interface that is used in students training to improve virtual palpatory diagnosis by allowing the user to follow and feel an expert’s motions prior to performing their own palpatory tasks [9,16].

Virtual Veins is a virtual reality training simulator allowing Healthcare Practitioners to acquire, develop and maintain the skills necessary to perform venepuncture in a range of realistic scenarios within a safe controlled environment [7]. After a practice or test session, the user can review their performance in an online report containing user and session details, an event log of the session i.e. skin/vein penetrations/retractions, a screenshot of the first skin penetration and metrics including skin insertion angle, skin retraction angle, bevel angle, vein insertion angle, vein retraction angle, vein diameter, vein penetration length and vein penetration depth.

Strong related application of haptics is education and training with medicine are those dedicated to rehabilitation. In [17] is introduced a haptic system for hand rehabilitation that combines robotics and interactive virtual reality to facilitate repetitive performance of task specific exercises for patients recovering from neurological motor deficits.

Since then, the use of haptic technology spreads in several domains of human activities. Educational haptic-based setups help teachers to better explain and students to better understand physical laws by visuo-haptic visualisations inside real time experiments.

The current accessibility of haptics technology together with the intuitiveness of using it represents enough arguments for applying haptics in education at all levels, starting from elementary schools [18]. From dedicated setups for teaching elementary school students simple-machine concepts [19] to complex ones [20], from dynamic systems [21], and modelling virtual proteins [22, 23], to experiencing multimodal educational virusology-oriented content [24] and applying haptic devices as tools for sculpturing [25] and even for developing writing skills [26], all these haptic-oriented solutions rely on the fact that haptics simulates and renders realistically the interaction forces that occur when the user come in contact with real objects.

This way, the user becomes more engaged in the proposed experience, not only by traditional means (mental, visual, and auditory) but also from a tactile perspective, and better immersed in the educational process because of the orthogonal perspectives given by sensorial data [27].

III. CHAPTER III - HAPTIC DEVICES

The haptic devices currently available on the market apply relatively small forces on the user (usually on the user’s hands and/or fingers) through a complex system of servoengines and mechanical links. There are numerous haptic devices on the market, and their price has decreased significantly over the past few years due to mass production. Among the most popular are Sensable’s PHANToM® Omni™ and Desktop™ [28] devices that can apply forces through a mechanical joint in the shape of a stylus. As recent as 2007, Novint, a company founded by the researchers of Sandia National Laboratory, marketed the very first commercial haptic device. Falcon Novint [29] has been released on the market at a very low price in conjunction with computer games in the USA, Asia and Australia. Novint licensed key portions of the technology used in Falcons from Force Dimension [30], a leading Swiss developer of high-end haptic devices like the Omega family illustrated in Figure 1.

A novel approach to implementing haptic feedback is through magnetic forces. Magnetic levitation haptic devices allow users to receive force-feedback by manipulating a handle that is levitated within a magnetic field. Users can translate and rotate the handle while feeling forces and torques from the virtual environment.
Compared with traditional haptic devices that use motors, linkages, gears, belts, and bearings, magnetic levitation uses a direct electro-dynamic connection to the handle manipulated by the user. Some of the advantages of this approach are: no static friction, no mechanical backlash, high position resolution, simulation of a wide range of stiffness values, and mechanical simplicity. Magnetic haptics has been considered in relation to surgical training systems [31].

The first commercial integration of a magnetic levitation haptic device is the Maglev 200™ Haptic Interface developed by ButterflyHaptics™ [32], illustrated in Figure 1(i).

Multiple problems arise in haptic applications interacting with deformable objects. For example, costly computation time, numerical instability in the integration of the body dynamics, and time delays etc., may occur. Lengthy computations are forbidden in haptic systems which need high simulation rates (around 1 KHz) to obtain realistic force feedback. The update rates of the visual component (i.e., graphic rendering) of the physical objects being simulated is of the order of 20 to 30Hz (frames per second). This difference in the simulation rates can cause an oscillatory behavior in the haptic device that can become highly unstable. Some of these problems can be alleviated with the use of magnetic levitation devices [32]; however, the development of applications in the area is in early research stages.

**IV. CHAPTER IV – HAPTIC APIs AND FRAMEWORKS**

In [34] it was realized an comprehensive study in what it concerns existing haptic APIs, focused on ReachIn commercial API, and on open-source APIs like SOFA, CHA13D, H3D, X3D, GiPSi and OpenHaptics.

ReachIn [35] is a modern development platform that enables the development of sophisticated haptic 3D applications in the user's programming language of choice, such as C++, Python, or VRML (Virtual Reality Modeling Language). This API was one of the first commercial ones that involve haptics. Its platform structure allows the development of multimodal interfaces and synchronizes haptic, graphic, audio or non-haptic devices.

SOFA (Simulation Open-Framework Architecture) [36] is an international, multi-institution, collaborative initiative, aimed at developing a flexible and open source framework for interactive simulations. Using a scene graph structure, SOFA provides several views in modeling 3D objects: a dynamic view that include masses and constitutive laws for the objects, a collision view that use
simplified 3D models of the objects in collision computation, and a visual view that uses a complex 3D graphical representation. SOFA assures the scene consistency between these models by using mapping modules. Moreover, SOFA implements complex real-time algorithms that use multiple representations of the simulated objects in the three views.

Computer Haptics and Active Interfaces - CHAI3D [37] is an open-source designed to facilitate the development of 3D modeling applications augmented with haptic rendering. It supports several commercial haptic interfaces such as Servo2Go and Sensoray 626 I/O board, IEEE1394 interface.

CHAI3D provides an easy solution to interface any haptic device with a specific computer-based application. CHAI3D framework allows extensions using modules for ODE [38] and dynamic engines that simulate rigid and deformable objects in real-time. Moreover CHAI3D enables the development of new classes, in order to integrate new haptic and visual rendering algorithms as well as drivers for new devices.

A popular open-source platform, H3D [39] is dedicated to haptic modeling that combines the OpenGL and X3D standards together with haptic rendering in a single scene graph that mixes haptic and graphic components. H3D is independent of haptic device multi-platform that allows audio and 3D stereoscopic device integration. H3D is conceived to support rapid prototyping. Combining X3D, C++ and the Python scripting language, H3D improves the speed of execution, when performance is critical, as well as high speed of development, when rapid prototyping is required.

General Physical Simulation Interface (GiPSi) [40] is an open-source framework that presents a flexible architecture, developed to simulate surgical procedures at organ level. The architecture interconnects computational and data models, developed by different research teams, quantitative validation of biological simulations together with software modules interconnections.

OpenHaptics toolkit [41] developed by SenseAble, includes the QuickHaptics interface, the haptic device (HD) interface (HDAPI), the haptic library (HL) interface (HLAPI), together with tools and drivers for PHANTOM® devices (PDD). The toolkit is accompanied by a solid documentation and a programmer’s guide.

V. CHAPTER V – OUR EXPERIENCE

The team of CeRVA [42] (Research in virtual and augmented reality) from the Faculty of Mathematics and Computer Science, Ovidius University Constanta started to experience the use of haptic devices in 2008, in the framework of Virdent project (PNII 12083/2008) that was oriented towards the preparation simulation in fixed dental prosthesis, as a noninvasive, feasible, providing necessary feedback learning, that offers to the student recovering from an erroneous situation facility, together with recording and real-time evolution of the student evaluation by the teacher [43].

Figure 2. Working sessions with Virdent (left) and HaptMed (right).
Then, in 2010 we started HapticMed project (POSCCE O.2.1.2/2009), the first 3D visual and haptic simulator for liver diagnostic through palpation in Romania (see fig. 2). This custom built simulator has enabled development of new expertise in haptic system development and integration for Romanian computer science and engineering students [44].

As opposed to commercial simulators for laparoscopic procedures, our simulators are a fraction of the cost and has been developed mainly with open source software. The results obtained so far point to direct applications in the medical industry and practice. The simulator can improve medical training thus helping save human lives.

We are in the process of assessing the simulator by the surgeon residents from the Regional Hospital of Constanta.

VI. Conclusions

The potential of haptic interfaces in support of practice based learning is proved worldwide. Even if the haptic hardware is more affordable, the development of haptic based simulations is hampered by the lack of existing software adaptability and extensibility.

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