Chapter 3.9
Haptic-Based Virtual Reality Dental Simulator as an Educational Tool

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ABSTRACT

This chapter describes the haptic dental simulator developed at the University of Illinois at Chicago. It explores its use and advantages as an educational tool in dentistry and examines the structure of the simulator, its hardware and software components, the simulator's functionality, reality assessment, and the users' experiences with this technology. The authors hope that the dental haptic simulation program should provide significant benefits over traditional dental training techniques. It should facilitate students' development of necessary tactile skills, provide unlimited practice time and require less student/instructor interaction while helping students learn basic clinical skills more quickly and effectively.

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INTRODUCTION

In a comprehensive virtual reality (VR) simulator there are two important aspects that ultimately impact the way users interact with virtual objects: the visual impression of an object and touch-enabled interaction with it. While touch is one of the most fundamental ways for people to perceive physical objects (Gardner, 1983), until recently VR simulators focused primarily on the audio and visual aspects of simulation (Laycock & Day, 2003). However, to explore an object of interest we would like to be able to sense its physical properties by applying forces to it (Van Shaik et al., 2004; Broeren et al., 2007; Bird & Gill, 1987). This is possible by using special mechanical tools, called haptic devices, that enable the user to feel the feedback forces (Thurfjell et al., 2002). Recent technological advances have resulted in the production of a variety of affordable haptic devices, such as PHANToM™ Desktop (Massie & Sallisbury, 1994), providing possibilities for creating sophisticated simulation systems with vastly improved touch-based human-machine interfaces. Haptics allows the user to feel, manipulate and interact with the object displayed on the PC monitor. The user can touch, move and feel an existing distant object indirectly through a robotic arm. Furthermore, haptics provide force feedback to humans interacting with virtual or remote environments since the robotic arm is able to provide preprogrammed guidance.

This chapter is dedicated to exploring the uses and advantages of haptics-based simulators as an educational tool in dentistry. Tactile skills training, so necessary in dentistry, is very time-consuming, and requires extensive one-on-one instructor-student interaction. Traditionally trained students do not feel what the instructor feels nor can they be physically guided by the instructor performing a procedure. At the same time, high visual acuity is required from the student.

To aid in solving many of these problems, a prototype haptics-based VR dental simulator for training first-year dental and hygiene students to do periodontal probing and detect caries active and non-caries active white spot lesions (PerioSim©) has been developed at the University of Illinois at Chicago (UIC) through joint efforts of the College of Dentistry and College of Engineering. The addition of haptics allows the trainee to feel and interact with onscreen objects. The device is designed for training and evaluation of performance in periodontal probing and white spot caries activity by dental students, hygiene students and practicing professionals. These technological tools being developed at UIC should aid in solving some of the pressing problems faced by dental schools, such as the decreasing pool of dental school instructors, the reduction in time instructors interact with students, and the limited time available to practice various dental procedures. Furthermore, computer technology can dramatically reduce the need for students to practice on patients.

SIMULATOR COMPONENTS

The simulator system consists of a high-end computer workstation with appropriate software (listed below), a haptic device, and a stereoscopic computer monitor with stereo glasses. The computer renders three-dimensional (3D) graphics that can be viewed with the stereo glasses, and operates the haptic device that provides a realistic tactile sensation. Onscreen VR instruments can be manipulated on this monitor by operating the haptic device stylus for sensing life-like contact and interaction with teeth and associated periodontal structures.

The haptic device utilized in the system is PHANToM™ Desktop (SensAble Technologies, Woburn, MA, USA). It provides a range of motion approximating hand movement pivoting at the wrist. The device includes a passive stylus and provides 6-degree-of-freedom (6-DOF) positional sensing and 3-DOF force feedback. The PHANToM™ haptic device connects to the PC via a parallel port (EPP) interface. The device allows the user of the simulator to move freely and explore the virtual environment with the stylus without feeling any unnecessary or unnatural forces. The tactile sensation is created by the actuators and breaks which are, in turn, controlled by the simulator software. There exists another variation of the PHANToM™ haptic device that can provide 6-DOF force feedback but this is extremely costly. The less expensive 3-DOF force feedback haptic device is used in this project. As such, only forces (and not torques) can be displayed by the device and the haptic interaction is effectively limited to

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