INEXPENSIVE DENTISTRY TRAINING USING VIRTUAL REALITY TOOLS

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Abstract

Dental medicine involves complicated and precise operations which require a long-term training and practice. The paper describes some of the procedures that are assessed in the framework of the VIR-PRO Romanian research project in order to increase the preparation and competitiveness of dental students, doctors in training and dental technicians by using dedicated Virtual Reality tools. The VIR-PRO project has three main components: a Virtual Learning Environment for dentistry represented by a web/cloud based tutoring platform, a Virtual Reality laboratory training phase and finally a physical training phase using 3D printed synthetic models. The second component implies the creation of a virtual 3D training environment containing the oral cavity with teeth and gums, associated with navigation and dental tools. The standard human-computer interface for dental training is using haptic tools to capture hands movements and stereoscopic devices to represent the environment. We are proposing in this paper a simpler and less expensive interface to be used before the classical one or as an alternative to it. It contains simpler hardware sensor devices without haptic feedback, like the Leap Motion controller, and 3D monitors or TV sets to show the environment. The feedback includes visual modifications and sound effects when medical procedures are performed in the oral cavity, without the tactile feedback. The development of Virtual Reality methods and technologies will lower drastically the costs of the educational process and will increase its quality because of the extended number of situations and complexity levels a student has to face before the invasive treatments on patients. There can be designed simpler and extremely inexpensive tools to be used at home and to precede/assist/replace the training in a Virtual Reality Laboratory, extending further the advantages of this type of training.

Keywords: dentistry, virtual reality, dental simulation.

1 VIRTUAL REALITY IN DENTISTRY

Virtual Reality (VR) is used in healthcare to improve both diagnostics and treatment. In dentistry, there are in use several dental training systems, most of them using haptic interfaces. They allow dental students to practice dental procedures in a virtual environment, monitoring and assessing their performance. The systems incorporate in some cases Artificial Intelligence tutors, which propose the correct techniques and guide the students in their training.

1.1 State of the art

The virtual reality training for dentistry started to develop at the beginning of the last decade, together with other VRs. Some of these systems use virtual reality and haptic devices as the main tools for assistance in dentistry education. For general information about the development of the field, one can check the several reviews [1-3] and for details, one can consult Table 1. We present here some of the most important systems for VR applied in dentistry with the year found for the first mentions and with useful references.

Many of these systems remained at experimental level and some are used in academia, but there are a few that become commercial achievements. The advantages compared with the classical training come from the reduced expenses, wide range of disciplines (implantology, dentistry, endodontics and prosthesis) and of clinical cases that are proposed, possibility to repeat a procedure towards faultlessness, easy and fair evaluation of the training progress, possibility to adapt the learning pathway to the student (many times automatically), reduced demand for teaching staff and simple adaptation/ improvement of the system.

Table 1. Important VR dentistry systems.

Year	System
1999	Virtual Reality Dental Training System (VRDTS) [4]
2000	DentSim [5]
2000	Iowa Dental Surgical Simulator (IDSS) [6]
2001	Intellifit Digital Restoration System/ FreeForm [7]
2002	PerioSim [8]
2004	Haptics-Based Virtual Reality Periodontal Training Simulator [9]
2005	Multi-Modal Workbench (MMW) [10]
2006	Virtual Dental Patient (VDP) [11]
2007	VoxelMAN [12]
2008	HAP-DENT [13]
2008	Dental Skills Training Simulator Using Virtual Reality and Haptic Device [14]
2008	Forsslund Systems Surgery Simulators [15]
2009	Moog Simodont [16]
2010	Virtual Dental Patient [17]
2010	Haptic Technology Enhanced Learning for dental students (HapTEL) [18]
2011	VirDenT [19]
2011	VirTeaSy Dental [20]
2011	iDental (A haptics-based dental simulator) [21]

2 VIRTUAL REALITY SOLUTIONS IN THE VIR-PRO PROJECT

VIR-PRO is the contraction for “Virtual e-learning platform based on 3D applications for dental prosthetics”, a Romanian research project aimed to increase the preparation and competitiveness of dental students, doctors in training and dental technicians. The project has three main components: a Virtual Learning Environment for dentistry represented by a web/cloud based tutoring platform, a Virtual Reality laboratory training phase and finally a physical training phase using 3D printed synthetic models.

2.1 VR models

We are using Blender to create the 3D entities that are included in the VR model. Blender is a free and open source 3D creation suite, available at https://www.blender.org/. It supports most of 3D procedures, including modelling, rendering, animation, simulation, etc...

The fundamental teeth and gums model is created using the Dmitrij Leppee's Teeth Model Set, available at http://www.badking.com.au/site/shop/human/human-teethby-dmitrij-leppee/. The model includes gums, tongue and individual teeth, all with the corresponding textures. One can choose from the 5 levels of discretization for the teeth and 6 levels of discretization for the mouth cavity (where the simplest one has 2310 vertices and the most complicated has 1134946 vertices). In Fig. 1 there are shown the lower teeth under processing in Blender.

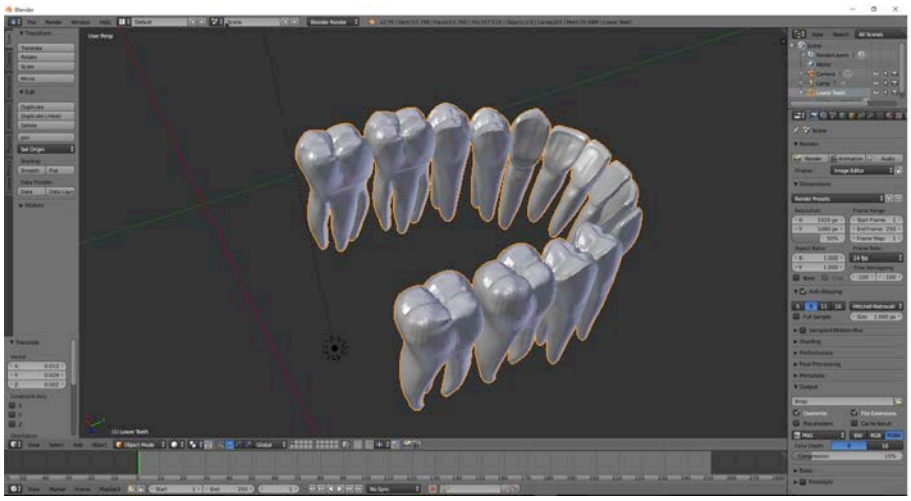

Fig. 1 Lower Teeth in Blender.

2.2 Development environment

The VR laboratory development is in its early stages. Some of the proposed solutions are created in Unity, a software development environment designed for creating games and interactive applications, available at https://unity3d.com. Unity is well known for its multiplatform 3D game engine with an extended integration of VR devices [22]. The Unity Asset Store is an extremely useful library of free and paid-for applications, 3D models, plugins, editor extensions, scripts, shaders, materials, audio and video files and many other. We work with free 3D models obtained from the Internet and modified or even created in Blender. We use Unity 5 Personal Edition with C# as the scripting language and several plugins for connection to the VR devices. We show in Fig. 2 the model of a mouth with two missing teeth.

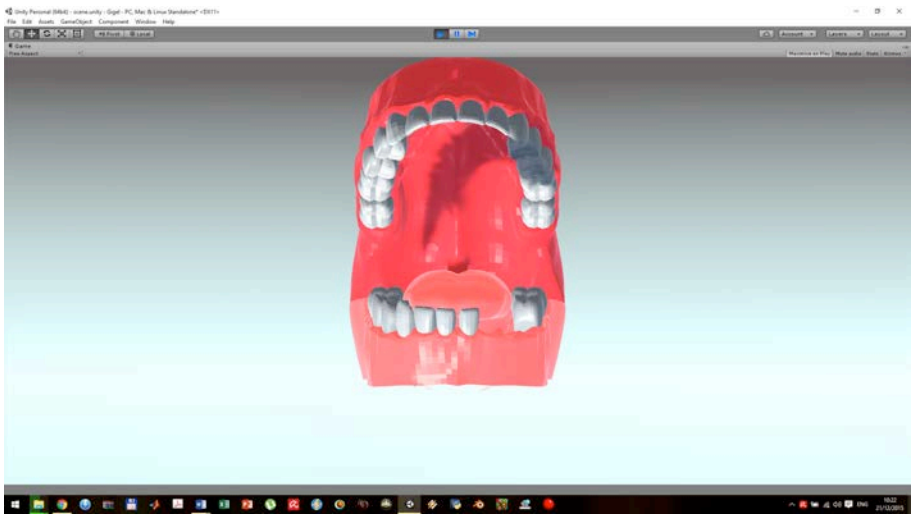

Fig. 2 Open mouth model in Unity 3D.

2.3 Classic solution

One of the solutions we are developing is the classical one, involving haptic devices and VR glasses.

2.3.1 Haptic device

Haptic devices are the human-computer interfaces that transform the hand movement to an input to the computer and allow the user to feel the reaction of the system, usually as an opposing force.

We are using in the development phase PHANTOM OMNI® Haptic Device, an economical instrument offered by Sensable Technologies (now part of Geomagic), shown in Fig. 3.

Fig. 3 PHANTOM Omni® Haptic Device.

The Phantom device has for the input part the positional sensing of joints with six degree-of-freedom and two integrated momentary switches and for the feedback it possess three degrees of force generation with up to 3.3 N.

To integrate the device in Unity 3D, we are using Unity 5 Haptic Plugin for Geomagic® OpenHaptics® Toolkit, available at https://www.assetstore.unity3d.com/en/#!/content/34393, provided by the Digital Design Studio from the Glasgow School of Art, Glasgow, United Kingdom [23]

2.3.2 VR Headsets

A VR headset is a device that integrates a person into the VR environment. It offers stereoscopic video, at least stereo audio and transfers to the computing system data like head movements or even eye tracking. The best known device is Oculus Rift, presented as its second development kit in Fig. 4. Oculus Rift tracks the head movements to provide 3D imagery to its stereo. Oculus is well integrated in Unity, as is can be seen from [24].

Fig. 4 Oculus Development Kit 2.

2.4 Inexpensive solution

The solutions presented in Chapter 2.3 are economic compared to the commercial solutions [20-21], which are considered efficient related to the practice on synthetic models in the laboratory, where the presence of a supervisor is also necessary. The price for the haptic device is several thousand USDs and it is 599 USD for the latest version of the Oculus headset – Oculus Rift, available from June 2016.

A current trend in serious games is to develop simple games that teach and familiarize population with medical procedures. For dentistry, the intent is both to educate and to lessen the anxiety, starting with simple kid games, like the ones from http://mydentistgames.com, up to more complicated ones like the teeth transplant from Surgeon Simulator 2013, available at http://www.surgeonsim.com, which can be played using VR headsets.

We will propose in the following a VR solution that is realistic, can be used for university training and is extremely inexpensive (several tens of USD). The training does not require the presence in a lab and can be done at home.

2.4.1 Leap-motion device

The Leap Motion Controller is a simple device, as shown in Fig. 5, having two cameras and three infrared LEDs. The cameras track infrared light with a wavelength of 850 nanometers (outside the visible light spectrum), being dedicated to hands and fingers tracking.

Fig. 5. The Leap Motion Device.

The Leap Motion has two different tracking modes - standard (on table) or as a head-mounted device. Because of its simplicity, it is affordable, with the price of 69 USD. The device is compact, small (a few centimeters) and light (32 grams), making it easy to be transported and used everywhere. The controller is well integrated in Unity through a plugin and several assets [25].

2.4.2 Google cardboard

The Google cardboard is a simple mobile phone VR platform developed by Google that uses a fold-out cardboard mount, as shown in Fig. 6. The system, presented at https://www.google.com /get/cardboard/, uses halves of the phone screen to represent the stereoscopic image and the phone sensors to obtain information about the head movement. The price is several USDs, making it a low-cost system that encourage the attraction to VR for the users and to the development of VR applications for the developers.

Fig. 6. The Google cardboard glasses.

The integration in Unity is not straightforward, because the applications for Google cardboard are running usually on the phone. One solution is to create side by side (SBS) graphics in Unity and to send the video stream to the phone using an USB connection and an application like Trinus VR, available at http://trinusvr.com/.

2.5 Solutions comparison

Tactile feedback is used for decades in entertainment and for a long time in virtual reality. For dental simulation, the haptic devices allow the users to touch and feel the entities in the virtual environment, perform operations like pushing, pulling, and cutting of soft or hard tissue with realistic force feedback.

On the other hand, home solutions like Leap Motion and Google cardboard can precede/complement the training in the Virtual Laboratory. They drop the benefit of “feeling” but come with the advantage of accessibility. They can be used to teach the student how to select the right tools and to handle them correctly.

For smartphones with stereo cameras, it is predictable the potential ability to replace the Leap-motion device, making in the near future the virtual reality training devices available outside the laboratory and with practically no costs.

3 CONCLUSIONS

The complexity, importance and demandingness of medicine made the researchers to enter the virtual spaces both for representation and records [26] and for simulation. The paper describe the state of the art for dentistry training using virtual reality and presents our results in the endeavor to create a Virtual Reality Laboratory for the practical part of dental education.

We propose a solution based on Unity 3D development environment and describe the integration of the classic solution and of a new, inexpensive one. The classical one is based on a haptic interface and on standard VR headset, while the other one uses the Leap-Motion device and the Google cardboard interface. This tender the idea of designing simpler and extremely inexpensive tools to be used at home and to precede/assist/replace the training in a classic Virtual Reality Laboratory, extending further the advantages of this type of training.

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