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VIRTUAL REALITY FOR EDUCATION AND TRAINING IN DENTISTRY

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***Abstract**: Dental students have to master, along with the theoretical knowledge, a lot of visual, practical and technical skills, essential to the dentistry profession. They include visual assessment of the medical condition, where the three-dimensional (3D) view differs from the images from manuals, first-rate psychomotor skills and understanding of the technical issues arisen in dental practice (restorations, implants, etc…). In recent years, both internationally and nationally, the invasive treatments made by students on patients were limited and are increasingly replaced by various alternative training solutions. Simulator laboratories with teeth replicas, typodonts (models of the oral cavity) and phantom heads are used for preclinical skills development. The paper presents the introduction of Virtual Reality as an e-learning tool for the dentistry education and training in Romania. It will precede and attend the current methods, accelerating the learning process before and during the training with artificial models and phantom heads, reducing the expenditure of artificial teeth, student time and instructor effort. Virtual Reality for education and training in dentistry implies the usage of a human-computer interface dedicated to this task. The working environment is a 3D representation of the dental tools and of the oral cavity with teeth and gums, accessible through stereoscopic devices. The input is capturing the hand/hands posture and movements using haptic devices or other hardware sensor devices that detects hand and finger motions. The feedback includes visual modifications, tactile feedback and sound effects when different operations are performed in the oral cavity. The use of these technologies will decrease the costs of the educational process and will increase its quality through individual training and self-assessment of the results.*

***Keywords**: dentistry; virtual reality; dental simulation; haptics*

I. E-LEARNING IN DENTISTRY

The paper describes some of the steps performed in the development of an e-learning solution for the prosthetics component of dental medicine, as proposed in the Romanian PN II Project VIR-PRO "Platformă virtuală de e-learning bazată pe aplicaţii 3D utilizabilă în protetica dentară"/ "Virtual e-learning platform based on 3D applications for dental prosthetics". The project has three constituents: creation of a Cloud based Virtual Learning Environment (VLE) for the theoretical knowledge, creation of a laboratory VLE based on Virtual Reality (VR) for the practical knowledge and of a laboratory practical stage based on manoeuvres performed on 3D printed biological counterparts [1, 2].

We will illustrate in this paper a solution suggested for the second component of the project, the VR module. We propose the use of Unity 3D, a software environment acknowledged for 3D games development, but also appropriate for creating VR applications [3, 4]. We will describe the solutions chosen for an application meant to enhance the efficiency and the quality of the practical training for dentistry learners, as well as the advantages of using Unity.

1.1 E-learning Platforms in Dentistry

The e-learning systems offer new ways to obtain instruction, learning and evaluation compared to the classical schooling. They have been introduced in several universities and are used in the medical domain because of its importance, complexity and demandingness. VLEs supports and improves the quality of teaching by introducing modern information technologies, facilitating the learning of new concepts and increasing the responsiveness and competitiveness among learners.

For Europe, the e-learning platforms for dentistry should meet the standards imposed by the Association for Dental Education in Europe (http://www.adee.org/). There are several university department web platforms that are working and they enable innovative teaching, quality assurance and standardization in the field, with the possibility of extending the national or international level. One of the most successful ones is ILKUM at University Medicine Mainz (https://ilkum.um-mainz.de). Another important one is the King's College London Dental Institute Universal Dental E-learning platform (UDENTE) (http://www.udente.org), a renaming of the IVIDENT program completed in 2010. At the University of Zurich, the virtual integrated medicine platform VAM. (http://www.vam.uzh.ch/de.html) has a component dedicated to dentistry. There are many other platforms worldwide, many of them in USA, and they provide dentistry training, even if in most of the cases, they are dedicated to the students of those universities.

There are platforms such as Online Dental College (http://www.dental-online-college.com /en/home/), which provides vocational training and continuing medical education in dentistry. On the social networking side, at Podlearn (http://www.podlearn.org/) there is a collection of podcasts that can help students in medicine and dentistry.

1.2 Virtual Reality in Dentistry

Virtual Reality is a computer simulated environment, allowing the user to interact with the world by getting stimuli and performing actions on the system. Dentistry is one of the fields well assisted by VR because of the several platforms that allow dentistry practice, replacing the invasive treatments made by students on patients or the work on artificial replicas.

There were developed many VR training systems using haptic technology, like Virtual Reality Dental Training System (VRDTS) [5], DentSim [6], Iowa Dental Surgical Simulator (IDSS) [7], Intellifit Digital Restoration System/ FreeForm [8], PerioSim [9], Haptics-Based Virtual Reality Periodontal Training Simulator [10], Multi-Modal Workbench (MMW) [11], Virtual Dental Patient (VDP) [12], VoxelMAN [13], HAP-DENT [14], Dental Skills Training Simulator Using Virtual Reality and Haptic Device [15], Forsslund Systems Surgery Simulators [16], Moog Simodont [17], Virtual Dental Patient [18], Haptic Technology Enhanced Learning for dental students (HapTEL) [19], VirDenT [20], VirTeaSy Dental [21], iDental [22].

II. VIRTUAL REALITY DENTAL ENVIRONMENT

The creation of a VLE based on VR for dentistry training implies the creation of convincing 3D assets to populate the virtual environment.

2.1 Dentistry Virtual Reality Environment

We use the application Blender (https://www.blender.org/) to create and to modify the 3D objects for the VR application. 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 around 2000 vertices and the most complicated has over 110000 vertices). In figure 1 it is shown a low resolution model for the teeth, gums and tongue.

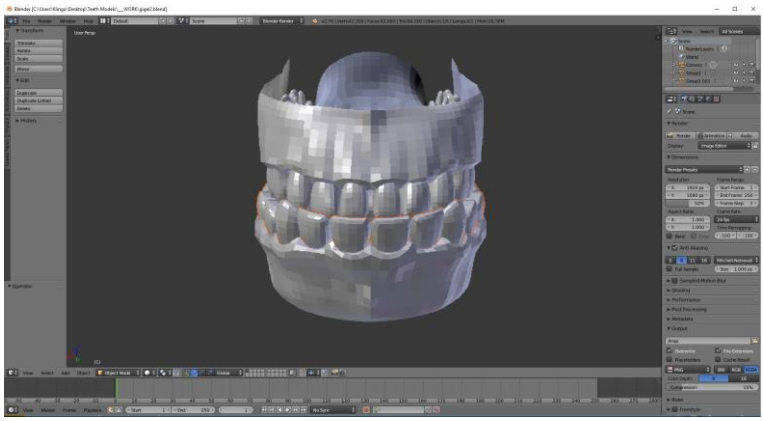

Figure 1 Mouth model in Blender

The Federation Dentaire Internationale (FDI) numbering system uses two digits to code the teeth, the first one being the quadrant and the second one the position and implicitly the type of the tooth. These codes will are used to identify the 3D objects/meshes representing the individual teeth. In the next stages of development, we are intending to create 3D models using real data and pathologies. The experience in using Cone Beam Tomography data for 3D reconstruction [23] will be used to obtain models that respect clinical cases.

We work with free 3D models obtained from the Internet and modified or even created in Blender, whose models can be integrated directly in Unity, the development environment. In figure 2 there are represented the models for the main dentistry tools.

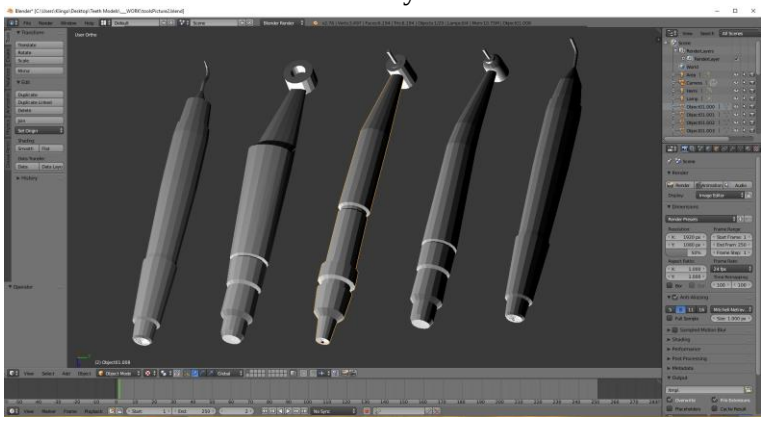

Figure 2 Set of dentistry tools

2.2 Development environment

The development of the VR laboratory for dental prosthetics is in its early stages. One of the solutions we are testing is being implemented in Unity, a software development environment available at https://unity3d.com. Unity is well known for its multiplatform 3D game engine and for the games created using it, but lately it is also used for VR interactive applications with an extended integration of VR devices [4].

The Unity Asset Store is an extremely useful online library of free and paid-for applications, 3D models, plugins, editor extensions, scripts, shaders, materials, audio files, video files and many others. We use Unity 5 Personal Edition having C# as the scripting language and we are using several plugins for connection to the VR devices, taking advantage of the richness of resources that come with the Unity environment. We show in figure 3 the model of the mouth and of a drill acting on the upper incisors.

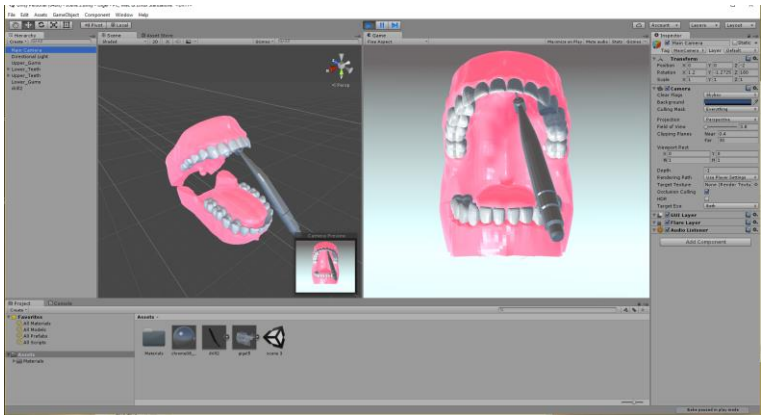

Figure 3 Open mouth with drill in Unity 3D

III. INPUT DEVICES FOR DENTAL VR

One of the great features of Unity is its large degree of various hardware devices integration. We will present briefly the devices that are used for the development of the application interface.

4.1 Mouse, keyboard and joystick

Unity supports directly keyboard, joystick and gamepad as *Conventional Game Input*. One simple method is to create virtual axes (directions) in InputManager and to map each axis to two buttons on the joystick, mouse, or keyboard keys or to the device movements.

4.2 The Leap Motion controller

The Leap Motion is a simple device dedicated to hands and fingers tracking, having two cameras and three infrared LEDs. The cameras record the infrared images produced by the LEDs in the neighborhood of the device. The controller is well integrated in Unity through a plugin and several assets [24]. The device can add virtual tools to the hands and can be used for simulations better than the conventional inputs. It will still lack the extremely important tactile feedback.

4.3 The haptic devices

Haptic devices are input devices having beside the sensing part some actuators that allow the user to feel the reaction of the system as an active force. We are using in this development phase the PHANTOM OMNI® Haptic Device (figure 4). It has six degree-of-freedom positional sensing and two integrated momentary switches for the input part and as feedback it possess three degrees of force generation up to 3.3 N. To integrate the device in Unity 3D, we are using Unity 5 Haptic Plugin for Geomagic® OpenHaptics® Toolkit [25].

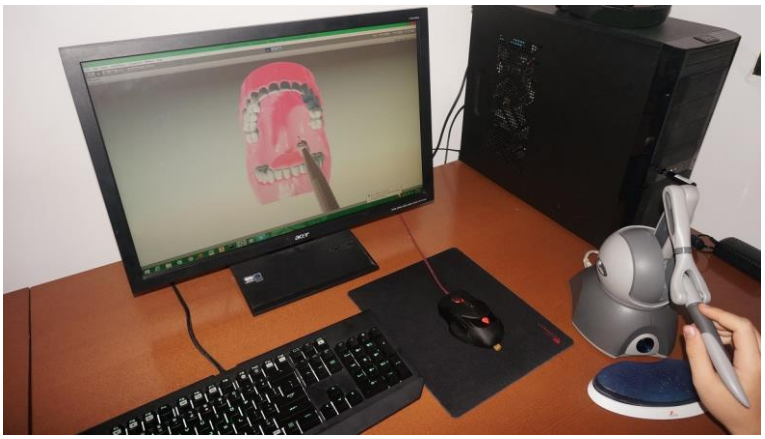

Figure 4 PHANTOM Omni® Haptic Device

IV. FEEDBACK FROM THE SYSTEM

4.1 Video

Virtual Reality requires stereoscopic video for immersion into the environment. There are several ways to obtain it, depending on the rendering devices. For notorious VR headset like Oculus there are SDK plugins [26] and there are several broad plugins packages for VR integration of a large number of devices, like .middleVR for Unity [27].

A simple and free stereoscopic solution is to use two Left-Right aligned cameras and to bond the results in a side-by-side frame, like in figure 5. The result can be used on passive 3D monitors and TV sets, but also on Google cardboard glasses, by sending the video stream to the phone with an USB connection and an application like Trinus VR, available at http://trinusvr.com.

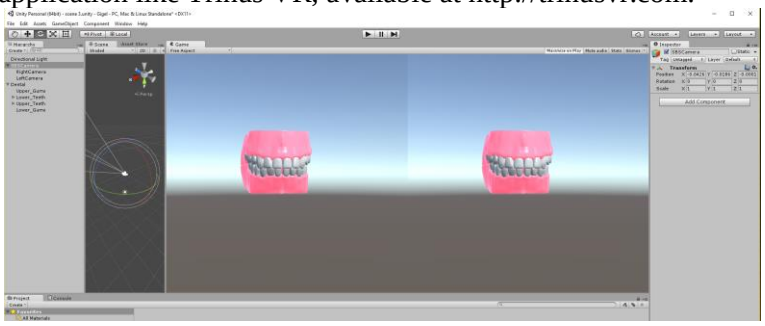

Figure 5 Side-by-side video in Unity

4.2 Audio

Auditory sensations play an important role in cutting simulations. We intend to record audio tracks for the drilling procedures and to determine the best audio cues depending on the speed of the turbine, the force exerted by the student and the type of tissue that is processed.

4.3 Tactile feedback

To simulate the tooth cutting procedure, we are developing a mesh deformation procedure, similar with [28, 29]. At the collision of the drill object with the tooth object, the direction of the drill movement is considered relatively to the normal to the tooth surface in the collision point. A force is applied in the opposite direction and the force and direction with witch the hand reacts is used to deform proportionally the mesh corresponding to the teeth.

We are in an emerging state with this procedure. The hand reaction force has to be converted to displacement for the teeth mesh nodes, without changing the structure of the mesh. The displacement coefficients should be different for different for types of tissue - enamel, dentine, pulp, so delimitations for these zones should be considered, making it an intricate procedure.

V. CONCLUSIONS

This short paper describes the partial results of a solution developed in Unity that is proposed as a VR module dedicated to dentistry training. From the multitude of trials to obtain VR training devices for dentistry procedures [5-22], just a few become commercial products and they are extremely expensive for the Romanian universities. In the framework of the VIR-PRO project we are developing a VR platform for practical training that will fit the Romanian medical schools needs.

We propose the use of Unity 3D as the software development environment and describe the solutions chosen and the directions to follow in order to develop a solution able to enhance the quality and the efficiency for the practical training performed by the dentistry learners.

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Reference Text and Citations

[1] Sandu, S.A., Neamţu, C.D., Grigorescu S.D., Bănică, C.K., Babiuc, I., Bisoc, A., Constantinovici, A., 2015. Introducerea platformei de E-learning în protetica dentară. Partea I, Introduction of e-learning prosthodontics platform. Part I. *In Revista Română de Stomatologie – volumul LXI, nr. 2, an 2015*, pp. 203-207

[2] Sandu, S.A., Neamţu, C.D., Grigorescu S.D., Bănică, C.K., Babiuc, I., Bisoc, A., Constantinovici, A., 2015. Utilizarea tehnologiei de realitate virtuală în protetica dentară / The virtual reality technology use in prosthodontics. *In Revista Română de Stomatologie – volumul LXI, nr. 2, an 2015*, pp. 121-125

[3] Linowes, J., 2015. Virtually Everything for Everyone, *Chapter in Unity Virtual Reality Projects - Explore the world of virtual reality by building immersive and fun VR projects using Unity 3D, 2015, Packt Publishing*

[4] Jerald, J., Giokaris, P., Woodall, D., Hartbolt, A., Chandak, A., Kuntz, S., 2014. Developing virtual reality applications with Unity, *In Virtual Reality (VR), 2014 IEEE, Minneapolis*, pp. 1-3

[5] Novint. Medical and Dental. *Online at: http://www.novint.com/index.php/medicaldental. Accessed 01 Feb. 2016*

[6] Dentsim. Introducing the "All New" DentSim v5.0. *Online at: http://image-navigation.com/home/dentsim/ Accessed 01* Feb. 2016

[7] Johnson, L., Thomas, G., Dow, S., Stanford, C., 2000. An initial evaluation of the Iowa Dental Surgical Simulator, *In Journal Dental Education, 2000 Dec, 64 (12)*, pp. 847-853.

[8] Dentsable. Intellifit Digital Restoration System. *Online at: http://www.dentsable.com/ index.htm. Accessed 01 Feb. 2016*

[9] UIC College of Dentistry, 2004. UIC Periodontal Procedures Training Simulator. *Online at: http://www.uic.edu /classes/dadm/dadm396/ADSreserch/Contents.htm. Accessed 01 Feb. 2016*

[10] Electronic Visualization Laboratory (2006). Haptics-Based Virtual Reality Periodontal Training Simulator. *Online at: https://www.evl.uic.edu/entry.php?id=1914. Accessed 01 Feb. 2016*

[11] Kim, L., Hwang, Y., Park, S.H., Ha, S., 2005. Dental Training System using Multi-modal Interface, *In Computer-Aided Design and Applications, 2:5, pp. 591-598*

[12] AIIA Laboratory, 2006. Creation of a Virtual Dental Patient. *Online at: http://poseidon.csd. auth.gr/LAB_RESEARCH/Latest/VirtRealMedicine.htm. Accessed 01 Feb. 2016*

[13] Voxel-Man. Dental Simulators. *Online at: http://www.voxel-man.com/simulator/dental/. Accessed 01 Feb. 2016*

[14] Yamaguchi, S., Yoshida, Y., Takeshige, F., Nagashima, T., Wakabayashi, K., Kawamoto, Y., Noborio, H., Kamisaki, Y., Sohmura, T., 2008. Dental Haptic Simulator to Train Hand Skill of Student, *In Proceedings of the 3rd MEI International Symposium*, 2008, pp.43

[15] Rhienmora, P., Haddawy, P., Dailey, M., Khanal, P., Suebnukarn, S., N., 2008. Development of a Dental Skills Training Simulator Using Virtual Reality and Haptic Device, *In NECTEC Technical Journal, 8, 20*

[16] Forsslund Systems. Home. *Online at: http://forsslundsystems.com/. Accessed 01 Feb. 2016*

[17] Moog, 2015. Haptic Technology in the Moog Simodont Dental Trainer. *Online at: http://www.moog.com/markets/medical-dental-simulation/haptic-technology-in-the-moog-simodont-dental-trainer/. Accessed 01 Feb. 2016*

[18] AIIA Laboratory. Creation of a Virtual Dental Patient. *Online at: http://poseidon.csd.auth.gr/LAB_RESEARCH/ Latest/CompGraphVis.htm. Accessed 01 Feb. 2016*

[19] Tse, B., Harwin, W., Barrow, A., Quinn, B., San Diego, J.P., Cox, M., 2010. Design and development of a haptic dental training system— HapTEL, *In Euro Haptics Conference, Amsterdam, Netherlands, 8–10 July 2010, pp. 101–108*

[20] Cerva, 2014. VirDenT. *Online at: http://cerva.ro/project/virdent/. Accessed 01 Feb. 2016*

[21] HRV. VirTeaSy Dental. *Online at: http://www.hrv-simulation.com/en/virteasy-dental.html. Accessed 01 Feb. 2016*

[22] Wang, D., Zhang, Y., Hou, J., Wang, Y., L, P., Chen, Y., Zhao, H., 2012. iDental: A Haptic-Based Dental Simulator and Its Preliminary User Evaluation, IEEE Transactions on Haptics, vol. 5, no. 4, Oct.-Dec. 2012

[23] Pavaloiu, I.B., Goga, N., Marin, I., Vasilateanu, A., Automatic Segmentation for 3D Dental Reconstruction, 2015. *In International Conference on Computing, Communication and Networking Technologies (ICCCNT 2015) Proceedings*

[24] Leap Motion Developer Portal, 2015. Leap Motion Unity Assets and Plugin. *Online at: https://developer. leapmotion.com /documentation/unity/index.html?proglang=unity. Accessed 01 Feb. 2016*

[25] Digital Design Studio, 2015. Unity 5 Haptic Plugin for Geomagic OpenHaptics Toolkit. *Online at: https:// www.assetstore.unity3d.com/en/#!/content/34393. Accessed 01 Feb. 2016*

[26] Oculus, 2015. Oculus Utilities for Unity 5. *Online at: https://developer.oculus.com/ downloads/game-engines/ 0.1.3.0-beta/Oculus_Utilities_for_Unity_5/. Accessed 01 Feb. 2016*

[27] MiddleVR, 2015. .middleVR for Unity. *Online at: http://www.middlevr.com/middlevr-for-unity/ Accessed 01 Feb. 2016*

[28] Rhienmora, P., Haddawy P., Khanal, P.; Suebnukarn, S., Dailey, M.N., 2010. A Virtual Reality Simulator for Teaching and Evaluating Dental Procedures, *In Methods Inf Med 4/2010, Schattauer, pp. 396-405*

[29] Wang, D., Zhang, Y., Wang, Y., Lu, P., 2003. Development of dental training system with haptic display. *In Procs. of 12th IEEE International Workshop on Robot and Human Interactive Communication 2003, pp 159–164*.