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VR Medical Gamification for Training and Education

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Abstract. The new virtual reality based medical applications is providing a better understanding of healthcare related subjects for both medical students and physicians. The work presented in this paper underlines gamification as a concept and uses VR as a new modality to study the human skeleton. The team proposes a mobile Android platform application based on Unity 5.4 editor and Google VR SDK. The results confirmed that the approach provides a more intuitive user experience during the learning process, concluding that the gamification of classical medical software provides an increased interactivity level for medical students during the study of the human skeleton.

Keywords. Virtual reality, video games, computer software applications, anatomy, skeleton, bone and bones.

1. Introduction

Gamification represents a confirmed but relatively new approach that integrates classic game design elements and mechanisms into everyday activities with the direct result of an increased engagement level of users. A large number of new applications are present in education, various business sectors and medicine to motivate the participants to reach their pre-established goals either by using AR (augmented reality) or even VR (virtual reality) oriented games. While AR applications are based on enhancing and adding of new, virtual data to the real world scenes usually seen trough special designed glasses (e.g. Google Glass [1], Magic Leap [2], Microsoft HoloLens [3]), the VR games offer a completely immersive experience to users because they can see only the 3D scene projected inside a head-mounted display (e.g. Oculus Rift [4], Avegant Glyph [5]).

The VR-based applications may help both patients and healthcare professionals to better understand or develop new treatments for various medical conditions. The VR rehabilitation of post-stroke adult patients [6] has been proven to bring numerous benefits over conventional therapy by providing additional real-time feedback and allowing the adjustment of difficulty levels during therapy.

Other studies [7, 8] show that VR may be used in pain management in order to increase pain tolerance levels or to distract patients from feeling pain when they are exposed to an immersive gaming experience. This approach might help patients in cases where opioid analgesics are not enough to alleviate pain and any additional, nonpharmacologic analgesic might help them during medical interventions.

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Medical students also might benefit of VR oriented environments where they can plan and practice complex operations without exposing the patients to complications that might come up during a real surgical interventions [9].

The current article presents an application for the use of medical students to better understand the complexity of human anatomy by exploring it in an immersive environment that leads to an increased interactivity level for anatomy lectures. This paper describes the process and results of the development of a complex mobile application that helps medical students to manipulate and learn the bones of a virtual human skeleton displayed in a virtual 3D scene. The application is designed as a game, avoiding boredom and providing learning the bones of the human skeleton interacting with the 3D objects through this application. Previously the team created a desktop version of the application, called Skedu [10], that is based on gesture interaction using a Leap Motion controller. One motivation for building a mobile application is based on the huge use of smartphones by the target public of the application. Another important motivation is using this mobile application for investigating which are the best values for the object's coordinates and improve interaction. Also to add new functionalities and integrate the VR headsets – as an alternative type of interaction than Skedu [10] application, both from the point of view of 3D objects visualization and as available functionalities.

2. Methods and tools

The novelty of this application versus the previous application is that it is designed for mobile devices and eliminates the need for a Leap Motion controller which has been replaced by a VR headset for interaction.

Virtual reality refers to artificial environments created on a computer that provides a simulation of reality so successful that the user can get an impression of physical presence close to real, also in some real places and imaginary places [11]. Virtual reality allows the user to interact with 3D objects both on a PC and on a mobile phone. Currently, the most popular VR systems are Oculus Rift, HTC Vive, Microsoft HoloLens and console Sony Playstation VR [12].

The most widespread equipment for virtual reality headsets use the mobile phone mounted inside. They are equipped with two lenses through which one can see two separate views/perspectives from the mobile phone at the same time in order to provide a 3D depth sensation.

The application uses Unity 5.4 software, as an editor of applications, games or experiments where one can write code in C# and JavaScript. The resulting applications from this editor may run on different platforms such as PC, Mac and Linux, iOS, Android, Windows Store, Xbox One and Samsung TV, either in 2D or 3D.

2.1. SQLite

In order to store information about human skeletal bones for the application, we used SQLite, a C library that implements an SQL database engine embedded, provides the ability to insert it into different systems and requires zero-configuration [13].

2.2. Google VR SDK

For an easier development of an Android mobile phone application we use Google VR SDK (Software Development Kit) [14]. To use Google VR SDK the latest version of Unity Editor 5.2 has to be installed. VR Google Android SDK allows building applications from Android versions 1.1 to 6.1. From this package, for interaction, we used the following items: Gvr Recticle and Gvr MainCamera.

For functionality and ensuring the best possible user interaction with the application, we use the following objects, each set on the proper position in 3D space:

- *Gvr Recticle* is basically a point on the mobile phone screen. With this point the user can find information about bone skeleton selected when the point was ranked a bone from the skeleton. This interaction object is a child object of the *Gvr MainCamera*, because it is a point of focus of the camera application on the surrounding objects. The point of interaction of the user with the application has been set with yellow (see Figure 1). The *Gvr Recticle* object has been set to the next position in 3D space: x = -0.1; y = 0.6; z = 0, and its size was set at one unit for all three axes x, y, and z.
- *Gvr MainCamera* is camera which allows visualizing all objects within the application. The camera duplicates 3D images resulting from the application in order to have one image for each lens of the VR headset. Basically, the screen is divided into two equal parts, so on the left and right side of the screen to have the same picture of application. The 3D image duplication should not mislead the user seeing only one 3D image of the object. *Gvr MainCamera* was set to position: x = 0; y = 1; z = 0, and its scale is a unit for all three axes: x, y, and z.

Bone is an object created in the application. The 3D human skeleton consists of 26 objects, each one representing a bone or group of bones of the human skeleton. The object *Bone* was added to the Unity Asset Store's editor. The 3D skeletal image is set at the position in 3D space Unity: x = 0.5, y = 1.5 and z = -0.6, and the scale of which is set at 10 units for each axis in 3D space.

The *Plane* is a 3D object to expose the *Bone* in front of the user. This item has been added to the menu of Game Object editor Unity. With the *Plane* object the user can imitate real walking on a surface. Position of the object was set to 0 for all 3 axes of 3D space and the scale was set to: x = 4; y = 1; z = 4.

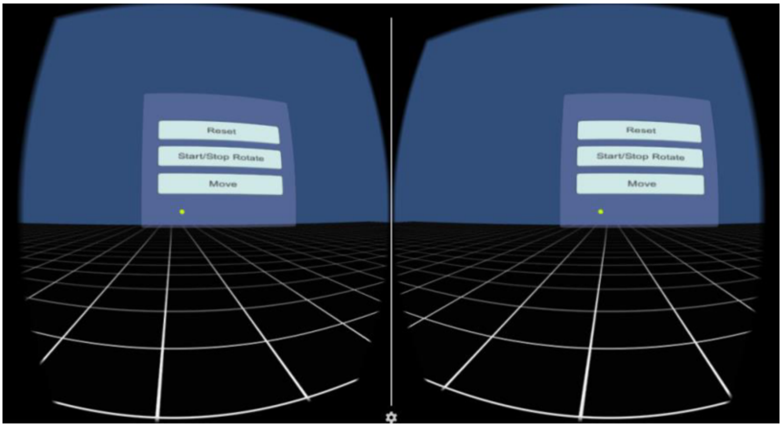

Figure 1. User control buttons

Other Game Object editor Unity menu objects are: *Point light* object for setting light in the application, *Text* object used to display information from the database when selecting a bone in the skeleton and the buttons: *Reset, Start / Stop Rotate, Move* each button representing the functionality of our application. Figure 1 presents an overview of previously described items and the Interaction buttons.

As previously mentioned in the description of the Game Object of the Unity editor, as menu items, buttons represent a functionality of the app allowing the user to interact with the 3D human skeleton. This interaction is possible by pressing the buttons and using the *Gvr Recticle* object mentioned above. The user may press the menu control button by placing the point of interaction on the desired button for 2 seconds.

The main features of the application are:

- *Turning On and Off the spin of the skeleton*. These two functionalities are present on the Start / Stop Rotate menu. First, pressing the button, the 3D skeleton will begin to rotate from right to left each second at an angle of 45 degrees, and the skeleton will make a complete rotation in 8 seconds. At the second press of the same button the skeleton will stop spinning and it will remain in the current position. This functionality is implemented with a C# script on its corresponding button: Start / Stop Rotate.
- *Movement in 3D space*. This functionality allows the user to navigate through the application. Basically the user can move in the virtual 3D space and may view the skeleton in different positions, like he has in front of him/her a real skeleton. This functionality is related to the Move button, and when pressing it, using the *Gvr Recticle* object, the user can navigate through the application. The user may stop this movement by pressing the Reset or interaction focused the yellow point down (if the position y of the object *Gvr Recticle* in virtual 3D space is less than -5). If the user will focus the subject *Gvr Recticle* down, so that the position of this object on the y axis (the height), to be less than or equal to -5, then it will stop the movement. The object *Gvr MainCamera* defines the functionality and uses a C# script where the object *Gvr MainCamera* is placed for moving forward. The script has been added to the Move menu button user control.
- *Selected bone information.* When selecting a bone from the 3D skeleton using the yellow point (object *Gvr Recticle*) the user receives information about the selected bone from the SQLite database on his mobile phone, and the selected bone information is displayed. Additionally, for a better view, the bone that is selected will change its original color in green. The code linking the database and selecting the right information, as well as color changing of the selected bone is a C# script added over the object *Gvr Recticle*.
- *Reset current position in the virtual 3D space*. To reset the position of the skeleton application and the current user location in the 3D virtual space uses a Reset button, setting all to default status.

The functionalities are provided by a VR headset that helps the user to control the application running on the mobile phone by moving his head, thus setting in motion object *Gvr Recticle* for the interaction with the 3D model.

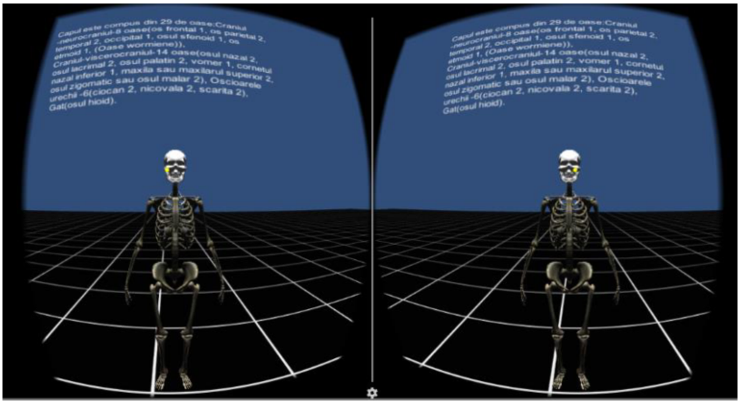

Figure 2. User information

3. Results

To set the application for a mobile phone and an Android system, after developing the application we moved to another development platform from the PC, Mac & Linux to Android and build the file ".apk" (option Build). In addition to the file ".apk" the editor had to prepare two external unity tools "Android.sdk" and "JDK 1.8".

Figure 2 shows the main functionality of the application, mainly presenting user information. The student may learn by placing the bones of the human skeleton, *Gvr Recticle* (yellow point) on 3D images (bones) that make up the entire 3D image *Bone*.

In Figure 2 the user places a yellow point (the object *Gvr Recticle*) on the head of the human skeleton and then automatically receives information about i\at in the top of the display.

For functionalities like the spin off rotation skeleton, and also the movement of the user through the virtual 3D space we use Equations 1-3:

Spinning equation:

$$R = m_i + k; \qquad (1)$$

where:

m_i - represents the measure of the angle of rotation at moment i (i = 1-> n; n = 8);

k - constant angle of 45 °;

R - measure of the angle of rotation

Spinning off equation:

$$R = mf + k; \qquad (2)$$

where:

mf is the measure of the angle of rotation in the final moment f (f = 1-> n; n = 8)

k - constant angle of 0 °

R - measure of the angle of rotation (angle equal measure when finally mf)

Table 1 presents the values for a rotation depending on the measure angles of rotation and the rotation moments. Note that a complete rotation of the skeleton requires 8 positions.

Table 1. Measure of the angle of rotation R for one rotation:

i	m_i	k	m_i+k	R	Rotation number i/n
1	0°	45°	0°+45°	45°	1/8
2	45°	45°	45°+45°	90°	2/8
3	90°	45°	90°+45°	135°	3/8
4	135°	45°	135°+45°	180°	4/8
5	180°	45°	180°+45°	225°	5/8
6	225°	45°	225°+45°	270°	6/8
7	270°	45°	270°+45°	315°	7/8
8	315°	45°	315°+45°	360°	8/8

Movement equation:

$$Pfc(xf, yf, zf) = Pic(xi, yi, zi) * s; \quad (xf > xi, yf = yi, zf > zi) \tag{3}$$

where:

Pfc(xf, yf, zf) - the final position of the camera on coordinates x, y, z;
Pic(xi, yi, zi) - the initial position of the camera on coordinates x, y, z;
s - constant vector speed

Defining these three equations: spinning (1), spinning of (2) and movement (3), has an important role in the functionality of the application and also in the study of the dependence of the positions (x, y, z) in the 3D virtual space of the objects that one interacts with, reported to the time and other 3D positions of other objects. It is important to specify that all these coordinates of the virtual objects are coordinates read from a virtual space and are very important in defining new functionalities in our application. We aim to find the gestures and their reflection to coordinates that provide the best interaction.

4. Discussion

The application is in tests using an Android 4.2 platform mobile phone. For now, from a technical point of view we concluded that in terms of memory space the application needs an Android system version at least 5.1 or better. The VR headset together with the mobile phone allows the user to modify the distance between headset and the mobile phone lenses and to modify the distance between the two lenses. These changes are done mechanically by each user from each corresponding buttons, changes depending on each user's eyesight. The application is scheduled to enter user testing with medical students of the first year from the University of Pharmacy and Medicine Timisoara. The testing is using a well defined plan assessing the sense of presence associated with virtual environments [15].

The application described in this paper enables the users – medical students or any interested one - to learn the bones of the human skeleton in an interactive way and a realistic 3D environment. Installing the application on mobile phones is easy, being the same as for any other regular applications. Also, the VR headsets offered by various companies are not very expensive. The application's functionality does not depend on the type or brand of the VR headset used. The application offers an easy to use and relatively cheap modern training solution.

Using VR headsets provides an alternative way to create applications for 3D visualization of virtual objects. Gamification, the concept that the application is based on, offers to users the possibility to learn and control the bones of the human skeleton in a realistic mode. The study of the coordinates of the positions of the virtual 3D objects reported to the time and other coordinates in the virtual 3D space open new opportunities to create new functionalities.

The next version of the application will be based on augmented reality (placement of virtual objects in the real world and viewed using VR glasses), the human skeleton will not occur in a virtual world, but will appear in the real world, so users being able to explore much better this skeleton.

In the future we plan to integrate a LEAP Motion controller for multimodal interaction.

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