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Mixed Reality Supporting Modern Medical Education

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Abstract. The paper presents new learning support for medical students exemplifying with several 3D applications for training on specific topics in medicine and investigates the impact on medical students. The applications were built using new concepts: Virtual Reality, Augmented Reality, as environments agreed by young people, and gamification to make learning easy and fun. Leap Motion and the VR headset are the devices to control the applications and provide a better human-computer/mobile phone interaction as compared to the current ones. The concepts and the new technologies to display/visualize the applications are the core of the Mixed Reality concept resulting from combining the 4 applications implemented for medical education.

Keywords. virtual reality, augmented reality, mixed reality, medical education

1. Introduction

Harnessing technology is a decisive act to push for change in medical education. For future physicians to practice at the peak of their abilities, medical education must be daring and contemporary, sliding beyond rooted curricula and approaches to meet the needs and to best develop the skills of a new generation of students. New technologies have already been put into practice in several universities where medical students learn anatomy or train to perform medical procedures.

New devices such as Leap Motion, Microsoft HoloLens, Oculus Rift or HTC Vive, are ever more frequently used in medical training to control or visualize 3D medical applications using Virtual Reality (VR) or Augmented Reality (AR). Virtual Reality is a representation of the real environment on a device (PC, TV or mobile phone), mirroring reality to such an extent that the user is under the impression of physical presence [1]. VR is mainly useful for educational purposes [2], post-injury recovery [3] or in training sessions for surgeons [4]. Augmented reality [5] is a combination of the real and virtual environment on devices with a video camera integrated into their interface.

Mixed reality (MR) is a new concept that has emerged in recent years, as a combination between VR and AR in 3D applications using cutting-edge devices for control [6]. The medical applications using MR are more and more numerous especially in medical education, in CT image processing or when performing medical procedures

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[7], oferring as suport for visualisation and coontrol devices: HTC Vive, Oculus Rift or PC. Such a system offers flexibility, devices being interchangeable adapted either to users' skills or in case of malfunction.

The use of medical education/training applications based on new technologies has become ever more popular among medical students. Many studies [8] [9] show that the number of applications in the field of medical education/training and the number of scientific papers written for this field has been increasing in the last 20 years and will, most likely, continue to grow at least until 2021. This increase is due also to the emergence of new technologies and of concepts as VR, AR, MR or gamification.

The VR, AR and MR concepts are put into practice within our research group in medical applications as Skedu [10], SkeduVR [11], SkeduAR or the AminoMotion [12] and tested with medical students from the Faculty of Medicine and presented in the in the followings.

Another innovative concept in all the applications developed by the group members uses the gamification concept. It entails the use of specific functionalities within applications designed to make the user unknowingly learn certain concepts (especially in medicine), making the learning process easy and motivational.

This paper's goal is to present the applications from the standpoint of the tools used to support their functionality, the concepts and the impact among medical students. A second objective of this paper is to state the issues posed when attempting to further develop the existing applications. All the applications are functional and may be demonstrated.

2. Methods and Tools

For that all 4 applications (Skedu, SkeduVR, SkeduAR, AminoMotion) made are the applications which are used in education has chosen to use the concept gamificatication, and the presentation of them to be in 3D. All the 4 3D applications were developed in the Unity Editor, version 5.3 and 5.6. The first 3 applications are intended for people who wish to learn the bones of the human skeleton using a more natural and easy to use technology and the fourth one is for the study of amino acids.

In terms of devices and concepts, the Skedu application uses the Leap Motion gesture-based technology. SkeduVR uses the Virtual Reality-based concept on a mobile phone equipped with the VR headset and SkeduAR uses the augmented reality concept on a mobile phone.

Since the Skedu and AminoMotion applications use the Leap Motion device for control we had to integrate a Software Development Kit (SDK) to make the connection between the Leap Motion Software and the Unity environment. The device recognizes hand gestures. 4 gestures are integrated into its software: Screen_Tap, Key_Tap, Swipe and Circle, and a developer may add new specific gestures. Leap Motion differentiates between the left hand and the right hand when performing certain gestures and recognizes each finger (thumb, index, middle, ring, pinky).

The SkeduVR application uses the Google VR SDK package for control and visualization, being compatible with the VR headset.

For the AR application (SkeduAR) we use an open-access database provided by Vuforia to store the real images for the interaction between the real and the virtual environment.

2.1. The Skedu Application

Skedu is a 3D Desktop Application designed to assist users in learning the bones of the human skeleton. It is controlled through Leap Motion gestures. The Skedu Application has 4 modules. Each module displays different categories of virtual bones of the human skeleton, grouped by size. Thus, the first module displays the whole skeleton, the second module comprises the long bones, the third module is comprised of the flat bones while the fourth module contains the short bones of the human skeleton.

The users learn the bones of the human skeleton as follows: when catching a bone of the skeleton the user receives as feedback the name of the specific bone (Figure 1) via the Pinch gesture implemented for the Leap Motion virtual hands. In addition, when catching/selecting any virtual bone of the skeleton, the specific virtual bone changes its color turning green.

Other functionalities implemented for this application are also related to the Leap Motion gestures. Thus the user may toggle between modules by performing the Screen_Tap gesture. The user may zoom in and out of the 3D image of the skeleton by performing the Swipe_Up gesture (to zoom in) and the Swipe_Down gesture (to zoom out) with the right hand. To rotate the skeleton the user must make a Swipe gesture with the left hand.

Figure 1. Skedu application interaction. Module 1

Figure 2. View virtual 3D skeleton in AR.

2.2. The SkeduVR Application

This application runs on a mobile phone and is used together with the VR headset. The mobile phone is inserted into the headset. SkeduVR resembles Skedu, with a virtual point situated in the center of the mobile phone screen for its control. This point is useful to find information about the bones of the human skeleton. When placing the virtual point on any bone of the skeleton the users find out the name of the selected bone. The virtual point may also be used to perform other operations on the 3D image of the skeleton such as: rotating the skeleton or moving it within the 3D space. The virtual point used to perform the interaction comes together with the use of the Google VR SDK package in the application. This point may be used to control the application if the user uses the virtual headset together with a mobile phone on which the application is running.

2.3. The SkeduAR Application

SkeduAR runs on a mobile phone and combines the real elements with the virtual elements. Basically, upon detection of a real image, through the mobile phone camera, a 3D virtual image of a human skeleton appears overlapping the real image (Figure 2). To store the real images employed to perform the interaction in the application we used the Vuforia open access database.

Students use this application if they want to visualize a skeleton in 3D when they don't have a real skeleton available. They can find information about the skeleton parts placing the finger on the image in front of the camera. The information about the virtual object will be displayed on the screen when, besides the real image for the interaction with the virtual object, the user's finger filmed with the phone camera is also displayed on the mobile phone screen.

2.4. The Amino Motion Application

Amino Motion is a 3D Desktop Application for learning the names of the amino acids formed by combining 3 nucleotides. The interaction is based on Leap Motion gestures. To find out the name of an amino acid the users must catch and introduce 3 virtual nucleotides, using the catching gesture implemented for the 3D Leap Motion virtual hands. The user catches a cube representing the virtual nucleotide (adenine, guanine, cytosine or thymine) and in return gets its name. After that, the user introduces the cube (the virtual nucleotide) in a virtual bowl where all the introduced nucleotides are combined. These actions are repeated 3 times, i.e. once the user has introduced 3 cubes (nucleotides) into the bowl the application displays the name of the resulting amino acid.

3. Results and Discussion

The main benefits of the previously presented educational applications are: the low costs for purchasing the Leap Motion device and the VR headset, the use of the VR and AR concepts to visualize 3D images as agreed young people environments, the possibility to use the applications as a complex of 3 or separately, personalized for the work abilities of each student, the gamification sending the message of a no-stress activity to users. The applications benefit of the gamification characteristics as: learning a thing without knowledge of it by the game, the motivation of the first bonus points in applications where user has learned from this, as well as the interest of the users to use applications since they lead to safe learning and without error.

The goal of the current paper is to present the new tools we developed to support medical education, from the design and development stand point, emphasizing the complexity of the process. The evaluation was performed on 2 of the applications at the beginning of the year with medial students that volunteered and the results will be presented in a future paper after ending the 4 evaluations. The test plans included the usability test objectives, methodology (equipments, participants' characteristics, and procedures), usability tasks description, usability metrics and usability goals. Skedu's 3D display manner and the Leap Motion gesture-based interaction manner are the main benefits.

SkeduVR and Skedu applications have been tested on the 34 students at medicine, and SkeduAR and Aminomotion applications and are in the process of testing.

SkeduVR was tested on a population of 34 first-year medical students. Following the testing sessions new ideas emerged for the further development of applications meant to help students to learn the bones of the human skeleton and of other Virtual Reality-based modules. The gamification concept is also employed in this application, through the interaction modality, using VR together with the VR headset.

Skedu AR will be tested on a population of 37 first-year medical students. The testing session will be carried out observing a specific methodology. This methodology will allow monitoring the impact of the application use among medical students as well as their comments with a view to developing new Augmented Reality-based application modules.

One of the benefits of using AminoMotion is that the user does not have to have any previous knowledge of chemistry or anatomy to be able to use the application. While using the application the user learns the names of all the nucleotides and of the amino acids formed by their combination. The interactivity part is thoroughly developed by using Leap Motion gestures.

In the above applications, we tested: the response speed of the 3D interfaces controlled by the new technologies, and the time to use a functionality (e.g using a Leap Motion gesture to zoom in and out a 3D image) by each user. The main parameters were set to 30 seconds for each user to use functionality and 3 frames per second for the response speed of the 3D interfaces. All users ranged in [0; 30] seconds for the use of a functionality, and a second use resulted in even better performance when using application functionality.

In our future work we intend to expand the applications by integrating new modules, drawing inspiration from the feedback received from the students who use the applications. Furthermore, we will also focus on the use of the new (VR, AR, gamification and MR) concepts in our future applications.

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