Intuitive Interaction for Exploring Human Anatomy in a VR Setup

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***Abstract*—A vast majority of VR applications use interaction based on hand-held controllers. In this paper we present a novel application for exploring Human Anatomy which allows intuitive interaction based on eye gazing, gestures and physical hand movements. Experiments have been conducted to evaluate: (i) hand motion recognition technology for the feeling of immersion and intuitive interaction and (ii) the VR application in aspects of user experience and learning comparing to covey information through traditional digital representation methods. Preliminary results demonstrate an advantage of the VR application and hand motion recognition in a number of aspects investigated.**

I. Introduction

Virtual Reality has gained in recent years a lot of attention and is used widely in many fields ranging from the humanities and the social sciences, going through the agriculture and medical sciences and reaching the engineering and natural sciences. A wide range of VR applications target training and learning activities [1], bringing Virtual Reality Learning Environments (VRLEs) [2] in the front-end of this technology. VRLEs in medical field [3], [4] have been used for training across a number of subfields, including surgical skills training [5] such as neurosurgery [6] and patient specific simulations [7]. In the majority of cases, VR applications use simple interaction based on hand-held controllers leaving the power of complete physical interaction integration [8] without the intrusion of wearable devices [9] unexplored. In this paper we present a novel application, allowing the exploration of the human skeletal system that allows intuitive interaction based on eye gazing, gestures and physical hand movements [10] using hands-free technology. The remainder paper is organized as follows: the 'VR Human Anatomy Application' section, where the developed application with its two subsystems are described with emphasis on the physical interaction integration; 'Experimental Design' where the conducted experiments related to hands' movements recognition technology are explained; and then the 'Results' and the 'Conclusions' are following.

II. VR Human Anatomy Application

A VR application for Human Anatomy has been developed. The user is immersed in the VR application by wearing a stereo head mounted display (HMD) with positional head tracking (Oculus Rift DK2) and can interact with it based on hand motion recognition technology (Leap Motion) that was mounted on the HMD. For the development purposes, the Unity Game Engine has been used. The application has as a purpose the familiarization of the user with the human skeletal system. A 3D model of a human skeleton is displayed and the user acquires relevant information through the interaction with the system. The application has two sub-components: the 'Human Anatomy Virtual Class' and the 'Human Anatomy Virtual Lab'. Both subsystems are described below with emphasis on the way of interaction used in each one.

A video demo, of the VR Human Anatomy application that was developed, can be found at youtube.com/getlabchannel → Videos → VR Human Anatomy.

A. Human Anatomy Virtual Class

1) Overview: The first subsystem provides information for the skeletal system, in a structural way, within a virtual class. A 3D model of a human skeleton appears laid on an operation table (see Figure 1) and then a series of ten quiz questions are followed.

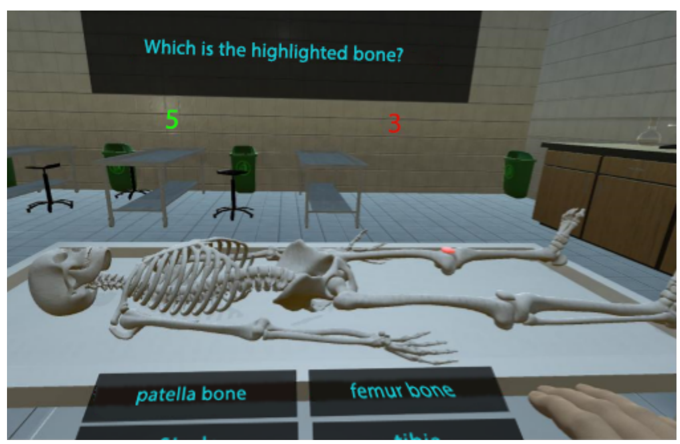
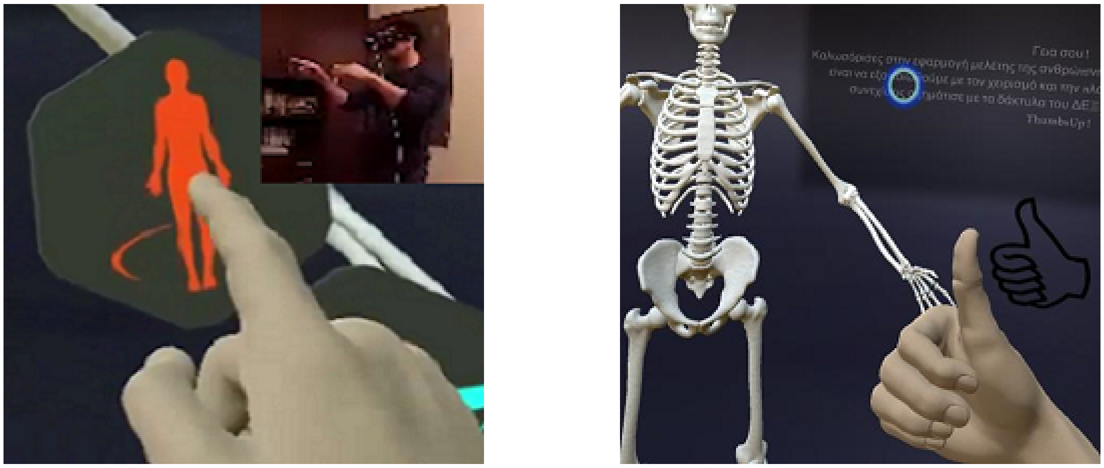


Fig. 1. Knowledge is gained in a structural way through quiz questions at 'Human Anatomy Virtual Class'.

For each one of the quiz questions, the system randomly highlights, with a light-red colour, a bone. The user should find the correct answer from four choices provided as possible answers. The quiz question and the four possible answers are displayed as UI text within the 3D space. Only one choice is the correct one. The user selects one of the four provided



(a) 3D menu

(b) Gestures recognition

Fig. 2. Virtual hands are co-located with user's real hands and are moving synchronously with them allowing intuitive interaction with the system.

options, as his answer, by touching with his virtual hand his choice. If the selected answer is the correct one, a 'win sound' is played and the 'correct score', appearing with green font colour, increases by one, otherwise a 'lose sound' is played and the 'wrong score', appearing with red font colour, increases. The overall score is displayed at the end of the quiz to the user.

2) Physical Interaction: The interaction of the user with the 'Virtual Class' subsystem is performed through hand movements recognition. The user can virtually touch his selected option, by clicking with his hand, the UI text that displays the answer of his choice. A virtual hand appears in the virtual environment collocated with the real hand of the user. All UI texts have trigger colliders on them. These colliders are activated whenever the collider that is attached to the point finger of the virtual hands enter their collision area, indicating the selection of the specific answer.

B. Human Anatomy Virtual Lab

1) Overview: The 'Human Anatomy Virtual Lab' is the second subsystem of the VR application in which the user can study the skeletal system, in a non-structural way, by exploring it in his own pace and in his preferred order. By exploiting physical interaction the user can disassembly the skeleton and explore the bones. Real time information is provided by the system, for the selected bone, in target's group users' native language.

2) Physical Interaction: The interaction with the 'Human Anatomy Virtual Lab' subsystem is performed using as input the movements and gestures of user's hands and his eyes gaze. The different types of interaction with this subsystem are described below.

Hands' movements recognition: Hands' movements recognition is used in the system in two ways; gesture recognition and interaction based on physical hands' movements. In user's view, besides the 3D skeleton representation, the left and right virtual hands appear, co-located with user's real hands and moving in real time and synchronously with them (see Figure 2).

A 3D display menu appears in the application which provides to the user a number of functionalities including rotation and translation of skeletal system's 3D model, reset position, zooming in/out etc. The user can select his desired functionality to be performed by dragging a slider or by clicking with his finger on the corresponding virtual button, Figure 2a, that works in a spring style way (returning back in their original position after they are pressed).

Moreover, the user provides instructions to the system with specific hand gestures, such as directing a 'continue' instruction with a right hand's thumb up gesture, Figure 2b, and toggling the 3D menu on/off with left hand's thumb up.

The most physical interaction is performed for bones exploration. The user can grab and hold any virtual bone by making the same movement with his hands as he would do in the physical world, if a real model of a skeleton existed in front of him. The user can then change the position of the bone (e.g. bringing the bone near to him), rotate it and explore it from any perspective with physical hand movements (see Figure 3).

To technically achieve this, colliders are used on virtual thumb and index fingers. The selected bone becomes child of the virtual hand, whenever the collider of the bone touches at the same time the colliders of the aforementioned virtual fingers while the two fingers have a small distance between them. This allows the grabbing of the bone and its exploration by simulating the physical way we perform this in the real world.

Eye gazing: Bones are selected based on the gaze of the user. The selected bone is highlighted, with the light-red colour, providing feedback to the user that the selection has indeed been performed (see Figure 4). The eye gazing has been implemented with ray casting. The hit bone is the one that is selected and knowledge information, such as its medical name and its use, are displayed to the user within the 3D scene.

Fig. 3. Grabbing and exploration of virtual bones with physical interaction at 'Human Anatomy Virtual Lab'.

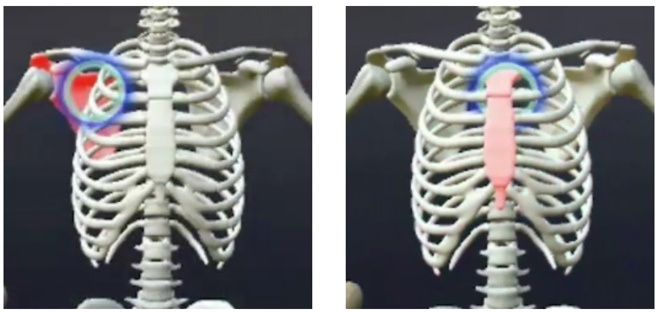


Fig. 4. Bone selection is performed using eye gazing.

III. Experimental Design

The purpose of this study was two fold: the evaluation of (i) the VR application and the integrated hand motion recognition technology in relation to the feeling of immersion and intuitive interaction and (ii) the developed VR application in aspects of user experience and learning comparing to covey information through traditional digital media methods. For these purposes, a between group study has been conducted, with 22 participants ($n = 22$) split equally in the two groups. Participants in the first group, named 'VR group' have used the aforementioned VR developed application to explore the skeletal system while participants in the second group, 'SP group', study the human anatomy through a slide-show presentation. The exact same information could be found using both methods.

Besides the demographic questionnaire, participants in both groups were given a pre-test knowledge questionnaire (pre-KT) with questions related to the human skeletal system. The same knowledge questionnaire was given to the participants after their experience (post-KT), either they had used the VR application or the slide-show presentation. The maximum score that one could get, by answering correctly in all questions, was 10 points. Regarding the evaluation of the method (VR vs slide-show presentation) used, another questionnaire (post-ME) was given to the participants of both groups after their experience, while a questionnaire for evaluating the hand motion recognition technology (post-HM) was given to the participants of VR group only. Post-ME and post-HM questionnaires used a 5 point Likert-scale.

IV. Results

Preliminary results based on analysis of the data of the post-ME questionnaire indicate an advantage of VR technology versus slide-show presentation method. A t-test evaluation demonstrate a significant difference between the two methods ('VR group' vs 'SP group') in a question related to the ability in understanding the 3D geometry of the objects (bones) ($p = 0.04$) and to a question related to the motivation in learning when using the specific technology ($p = 0.05$), both in favour of VR technology. Moreover, the feeling of entertainment was higher in case of the 'VR group' with a mean $M = 4.2$ in a lLikert-scale from 1-5 with 5 indicating completely positive and 1 completely negative feeling, comparing to 'SP group' ($M = 3.6$).

In contradictory, based on the analysis of knowledge tests (pre-KT and post-KT) the results were not that promising for VR technology. Even though participants of both groups demonstrate an increase in their learning performance, participants in the 'SP group' demonstrated a higher increase based on comparison of the pre- and post- test related to the participants in the 'VR group' (see Figure 5). We speculate that this is due to the fact that the unprecedented experience (e.g. in aspects of a new way of interaction and exploration) that the participants should come across in the VR setup, affect their learning performance in gaining knowledge information. This is inline with Salzman's model [11] for complex conceptual learning. The above results are also inline with other studies where users report enjoying the use of VR technology while there is no advantage in aspects related to the increase of learning performance [12], [13].

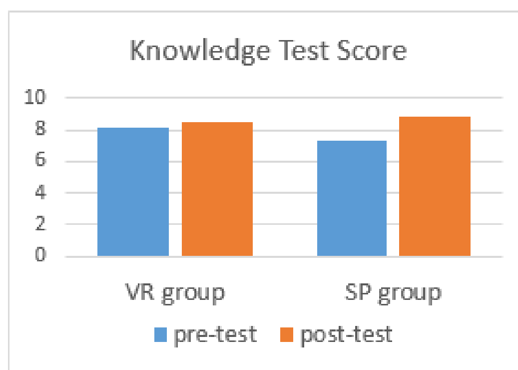


Fig. 5. Both groups had an increase in learning performance with the participants in the slide-show presentation group demonstrating slightly better results.

Despite that, the analysis of post-HM data demonstrate really encouraging results in learning affordances [14] such as enhancement of spatial knowledge representation and increased motivation and engagement. Participants in the 'VR group' rate the VR application using hand motion recognition

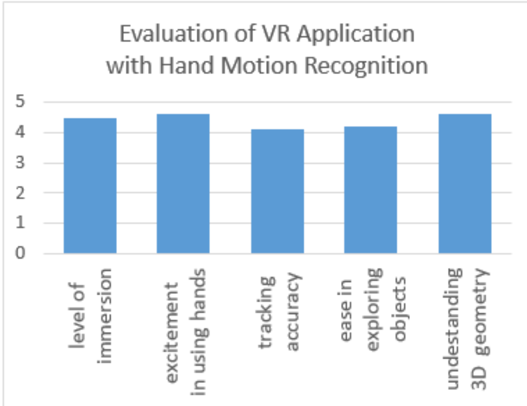


Fig. 6. VR application with integrated technology of hand motion recognition rated with high scores in a number of aspects.

technology with very high scores in a number of aspects: (i) increasing the level of immersion, (ii) the excitement in using hands for interaction, (iii) accuracy of tracking hands' movements , (iv) ease in handling the 3D virtual objects (v) facilitating the understanding of the convey information. The mean, for each one of all of these aspects, was greater than 4 ($M >= 4.1$), with 5 indicating the maximum positive rate. The results of the post-HM questionnaire's data analysis are shown in Figure 6.

V. Conclusions

Nowadays many technologies exist that allow innovative exploration of virtual environments. Exploring such technologies enhance the experience in Virtual Reality setups and facilitate the physical interaction, contributing in maximization of VR capabilities. Further investigation [15] is needed in how the potentials of these technologies can be exploited efficiently in aspects further than interaction and user engagement, such as in maximizing the information conveyed to the user by the system and achieving increase in learning performance.

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