Gamification of Hand Rehabilitation Process Using Virtual Reality Tools

Using Leap Motion for hand rehabilitation

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Abstract— **Nowadays virtual reality (VR) technology give us the considerable opportunities to develop new methods to supplement traditional physiotherapy with sustain beneficial quantity and quality of rehabilitation. VR tools, like Leap motion have received great attention in the recent few years because of their immeasurable applications, whish include gaming, robotics, education, medicine etc. In this paper we present a game for hand rehabilitation using the Leap Motion controller. The main idea of gamification of hand rehabilitation is to help develop the muscle tonus and increase precision in gestures using the opportunities that VR offer by making the rehabilitation process more effective and motivating for patients.**

Keywords-Leap Motion; virtual reality; gamification; modeling; Unity 3D; bionic controlled robot arm; 3D printing.

I. INTRODUCTION

Overwork, injury and geriatric complications, such as stroke can all cause hand dysfunction, totally or partially, which directly diminish the quality of life. Sometimes it requires a long term therapy to restore the total functionality of hand, which sometimes very molesting process for patients. To eliminate boringness of the therapy it is better to use state-of-the-art technology and adapt them into the game [1]. Effective therapy must be intense and requires the continual repetition of relevant functional tasks [2]. Virtual Reality (VR) can provide patients with a fun interactive environment, in which they can be guided to maintain high quality and intensive physiotherapy. VR and games have been shown to be beneficial in improving upper limb function and active daily living when used as an adjunct to usual care or when compared with the same dose of conventional therapy [3],[4].

We developed a game using Unity 3D, it is called Escape game. The game has different options, task and exercises related to 3D grabbing, reaching, pointing, lifting, throwing and other exercises for hand rehabilitation to achieve the above goals. Main component of our VR hand therapist is the Leap Motion which tracks hands. All items and the structures of the game were created in Autodesk 3D Max and Cinema 4D, then imported to the Unity environment.

II. METHODOLOGY, SOFTWARE AND HARDWARE

A. *Existing VR tools for gamification of rehabilitation*

Rehabilitation and health care centers are interested to have have computational systems based on virtual reality games, which focuses to improve the motor training and motor learning through both, fine and gross movement exercises [5]. As rehabilitation process sometimes take long period of time, these centers are trying to find the new methods of training the patients. On area of focus for these kinds of hospitals is accessibility and low-cost hardware. Here are some examples of use of VR rehabilitation systems. As a first remarkable example is the system BioTrak [6] which is a platform for training and rehabilitation of many diseases as result of some pathology. This system includes a magnetic tracker which can detect gross gestures from the upper limbs. The IREX system IREX (Interactive Rehabilitation and Exercise System) [7] is another example, which includes a wide range of interactive games focused in gross motor movement for the arms. Listed systems have high efficiency, although their prices are expensive due to

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the employed hardware. Thus, leads to necessities of low-cost options. Thanks to new technologies that updated almost every week, we have hardware, which provided by the video game consoles emerged as a brilliant opportunity, because they are designed to obtain the 3D position of game players in real time. Because of that, researches focused on the Leap Motion, Myo armband, Microsoft Kinect, Nintendo Wii, PlayStation Move, and others VR technologies are prominent examples [7-18]. Currently, S. Chen et al. [9] developed a Hand Gesture Based Robot Control System Using Leap Motion. In addition, researches like those made by Hayes et al. [18] and Lange et al. [19], show platforms of video games for rehabilitation using the Kinect as a rehabilitation tool.

There are two types of devices for recognizing gestures available on the market that enable independent developments of the third-party developers [20]:

• Motion sensing systems – bracelets, rings, bracelets under elbow, gloves and pointers;

• Computer Vision Systems [22],[23].

Main advantage of the motion sensing gesture recognition devices from computer vision systems is that they have enormous library of possible gestures enabled by the precision sensor array. This may include things such as “air handwriting” recognition and the subtle nuances of sign languages. Furthermore, the gesturing itself may be less conspicuous because it can be done with smaller movements made closer to the body thus calling less attention to the user.

The disadvantage is that motion sensing devices are separate pieces of hardware that must be toted along with the user. They have the additional burdens of needing their own power sources and having to establish and maintain a radio connection to the human-computer interface (HCI).

Next session presents the software and hardware used during the experiment and while creation of the game.

B. *Software and hardware*

The game aims hand therapy patients, taking long term rehabilitation. Also as it was mentioned before, software and hardware needed to create this game or system should be cheap and portable for the patients. The best way to achieve this goal is to allow the patient to access virtual therapy exercises specified especially to her/him, with the option of selecting preferred games and exercises. In this section, we discuss the hardware and the platforms used:

• Unity: A platform that is used to build two and three-dimensional games and environments. It is very powerful due to its ease of use and abundance of documentation [19]. As the presented research dedicated to make hand rehabilitation a more exciting experience, the environment of the therapy should be interesting, with different levels of difficulty, so that it would encourage and motivates the patients to do his/her exercises.

• LEAP motion is a hand gesture detection device. It is manufactured using 2 cameras and 3 infrared LEDs (see Fig. 1). It detects hands, wrist and elbow positions and movements in three-dimensional space. LEAP motion setup is simple as it only requires the installation of the SDK from the LEAP motion from official website. LEAP motion is chosen in this work to follow patient’s hand movements during the game. Based on a study that was carried on in 2013, the deviation of LEAP motion measurement in a static position (where the LEAP motion device will not have to move throughout the exercise) was 0.20 mm independent of the axis. In the x-axis, the deviation is better where it is only 0.17 mm [20]. It has an accuracy of 76.07%, 74.2 % and 73.07 % to detect fingertips distances, fingertips angles and fingertips elevations respectively [21]. LEAP motion supports many platforms to allow implementation of new applications. Holmes, Charles, Morrow, McClean and McDonough used LEAP motion to create a model of arm motion tracked in 3D by a Leap Motion controller for virtual reality upper arm stroke rehabilitation [24]. In 2016, Sourial et al used LEAP motion to create virtual coach for hand rehabilitation of stroke patients [25]. LEAP motion supports Unity.

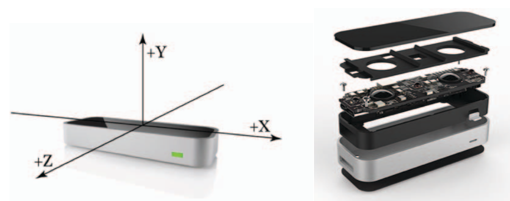

Figure 1. Leap motion device and 3D representation.

A virtual environment was developed in order to adapt the scenario as much as possible to the patient’s reality. The participant was asked to sit on a chair and to have his forearm resting on a small table nearby. movements on the mirror was used to increase the sensorimotor correlations to induce body ownership.

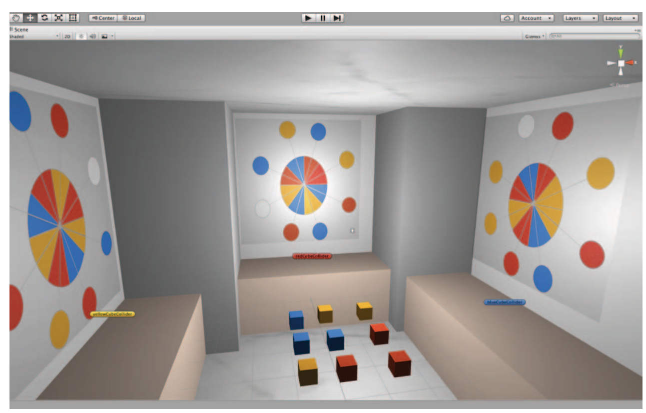

Figure 2. Exercise room capture

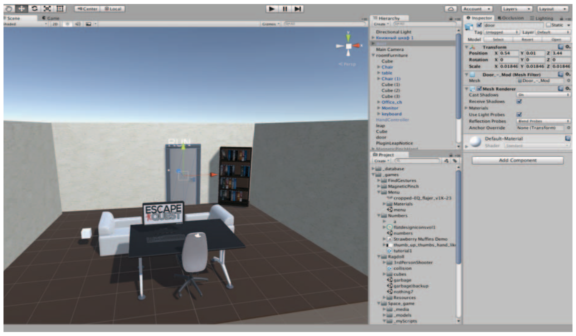

Figure 3. Escape game window

When using Leap Motion it will get a tactile feedback of the graphic hand representation. As shown in the Figure 4, there are two options, when patient can choose the hand representation either human or robotic. This is something really important which can be used to bring the virtual world closer to re-ality in a way that the user can interact with everything as he would do in his everyday life, getting a totally immersive experience.

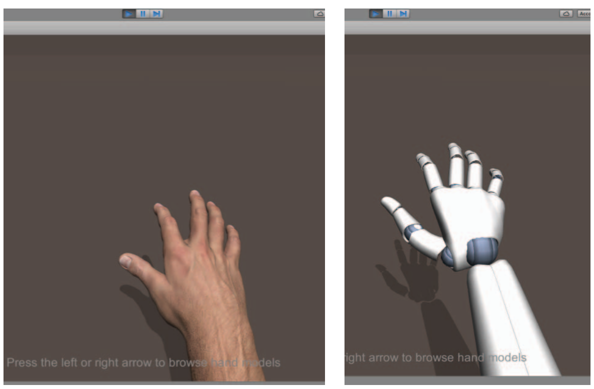

Figure 4. Choosing the hand representation mode: human or robotic arm

III. Future Work

Currently, we are performing further experiments with the Leap Motion and bionic hand. The experiment tends to focus on training the people deprived of their limbs, who need prostheses and needs to train their bionic limbs. For experiment we already printed out on 3D printer the necessary parts of bionic hand (see Figure 5).

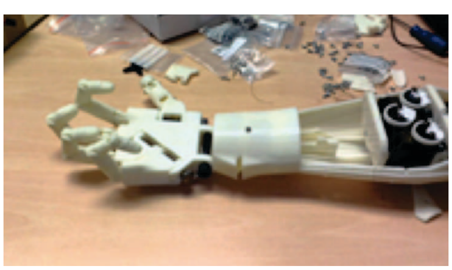

Figure 5. 3D printed bionic hand

We are going to use MYO armband, Raspberry Pi, servos to control the bionic hand. When the MYO armband was wearing a man's forearm, starts the calibration algorithm on Raspberry pi, i.e. the person alternately performed five gestures (Fig. 6), after each gesture occurs vibration, which means a change of gesture. After calibration the recognition of gestures performed with a previously stored, and the similarity of gesture command is transmitted to the servos.

Also, it is of interest to examine whether the Leap Motion is a good device to provide feedback or advice to users for improving movements made according to the prescribed ones. In the future we would like to create the system which will allow to patients to score the points for their exercises and see their progress during the therapy.

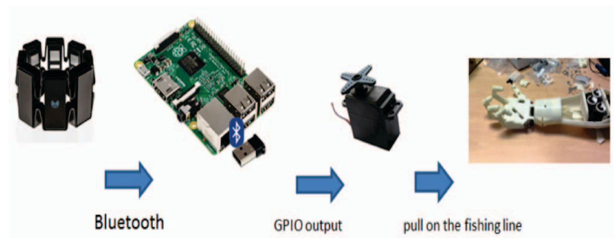

Figure 6. The work of sequential circuit system

IV. Conclusion

The purpose of this paper is gamification of the hand rehabilitation process using Leap Motion technology. We proposed the game that helps to straighten and train the hand muscles by executing different virtual reality tasks related to ordinary life actions, such pick up the items, move household items, match the color blocks, trough trash, hold and place items. In addition, the main purpose of this manuscript is to introduce a simple and straightforward implementation of Leap Motion into rehabilitation process.

We believe that the Leap Motion Controller technology would be beneficial and will give the opportunity to realize different human-machine interaction applications in the field of Activities of Daily Living (ADLs), because of its compact size, high performance and precision, and of course low cost.

Combination of Leap Studio application with 3D printers [26] will open up opportunity to designers/artists, end-users to bring their creative ideas into real life. Furthermore, this technology is very useful in different areas of human activity, there can be developed new types of interactive games, Leap Studio can also be useful in medical science, in education.

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