ÖZYEĞİN UNIVERSITY
FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE

CS 401

2019 Fall

SENIOR PROJECT REPORT

In Virtual Reality Environment Disabled Arms Training

By

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Declaration of Own Work Statement/ (Plagiarism Statement)

Hereby I confirm that all this work is original and my own. I have clearly referenced/listed all sources as appropriate and given the sources of all pictures, data etc. that are not my own. I have not made any use of the essay(s) or other work of any other student(s) either past or present, at this or any other educational institution. I also declare that this project has not previously been submitted for assessment in any other course, degree or qualification at this or any other educational institution.

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Signature:

Place, Date: Özyeğin University, İstanbul, December 31, 2019

Abstract

The project aimed to create realistic virtual reality environments and virtual arm for the people who have disabled arm. They can use their virtual arm as they used in real life. To increase the sense of reality using the data gathered by Leap Motion hand tracking using the able-bodied arm to create realistic motions in virtual reality environment. During the first step of the project, realistic world and implementing hand tracking for the real arm implemented. This report examines in depth analysis of the first step of the project and also future works will be done in the second step. For the future work the machine learning algorithm will be implemented by using the data we gathered from leap motion and MYO arm band.

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I. Introduction

Because of many reasons people are losing their limbs. Losing arm is very common injury and current medical solution are very expensive to make a prosthesis. However, rapidly growing 3D printing technologies are enables people to make their arm prosthesis. After printing arm frames, all they need is a device that provides data from muscles. There are several devices such as Myo Armband provides hand gestures by reading muscles' movement. However, they are recognizing very little amount of gestures; therefore, devices have to be trained personally. For personal training, able-bodied hand can be used for detecting their position and orientation; therefore, real-time hand tracking is needed to be implemented for collecting data of both position and orientation.

According to our researches, there are 3 academic article that focuses on this topic. The main topics of these article are, evaluation of Leap Motion controller and Oculus Rift for virtual-reality-based upper limb stroke rehabilitation , patient training for functional use of pattern recognition– controlled prostheses and Validity of the Kinect and MYO armband in a serious game for assessing T upper limb movement.

Leap Motion enables to collect data of position in 3D and orientation in 2D. Using immersive system, users can be interacting with objected by visualized hands and fingers thanks to the data provided by Leap Motion. Creating immersive system, HTC Vive Pro used to maintain the virtual reality and Unity3D game engine used for visualization. For the project, combination of two different methods which are hand position tracking by capturing position of the palm (forearm) using depth camera and immersive system in virtual reality solved problem to create a scenario that can be used for training. Using Virtual Realty provides an opportunity to create more scenarios and by using rapidly growing technology better results can be formed.

The following sections much more details about project can be examined. Rest of the article contains background, problem and solution, used techniques and methods, related works and future aspects of the project.

II. Background

Listed tools, techniques and devices used for the project.

- **Unity3D:** Unity is a cross-platform game/graphic engine which supports cross platform application development. Additionally, Unity has better support for the Virtual Reality development compared to other graphic engines such as CryEngine and Unreal Engine because of the plugin supports for developing process. This is the main tool for the developing process of project.
- **C#:** The programming language used for the project. The graphic engine we used which is Unity is supporting only C# language. Besides the previous versions of Unity supported java Script too, we are using the latest and stable version of Unity.
- **JetBrains Rider:** Rider is a cross-platform .NET IDE based on the IntelliJ platform and ReSharper which support C# and works with Unity3D. At this project we used rider to edit and implementing the C# codes for the Unity. Simply it is used as a code editor for Unity.
- **Visual Studio 2017:** The IDE for editing and building C# codes for unity. At this project we are using visual studio to edit the project codes for unity3d using C# which is a supported language for the Unity.
- **Blender:** Blender is free and open source 3D creation engine. During the project blender used for rigging and modelling. Since it is free application and we can get FBX format which is one of the supported formats at Unity we decided use it to create objects. Additionally, for the rigging process we used blender because of its detailed resources for rigging.
- **SketchUp:** SketchUp is a 3D design software. During the project it is used for creating realistic props and scene for the project.
- **OpenVR:** It is a software development kit and application programming interface developed by Valve to support SteamVR and other virtual reality headset devices.

- **SteamVR Plugin:** Valve maintains this Unity plugin to smoothly interface with SteamVR. It is developed for unity to provide connection between steamVR and unity. We can get all the tracking data from controllers and headset by using the SteamVR plugin.
- **HTC Vive Pro:** HTC Vive Pro is the virtual reality glasses used for the project that can support up to 4K graphic resolution that increase the level of reality. Additionally, HTC Vive pro has more advanced depth cameras located on the VR headset. For the project we used only Headset of HTC Vive pro and disabled the controllers.
- **Leap Motion:** The device used for hand and finger tracking by using the depth camera inside it. The device is generally used for virtual reality applications, however there are some desktop applications developed for the leap motion at windows and Mac OS platforms. Generally, it is used as a mouse for the desktop applications by detecting limited number of movements of hand and fingers.

- **Leap SDK:** The tool developed by Leap to get hand tracking data from leap motion. The SDK supports the application development on Unity3D for virtual reality and desktop. Also, by using the SDK, leap motion can optimize for the systems that have lower resources to increase the frame per second.

- **Lab Usability Testing Method:** The 10 person we choose did usability test for our project at OzU VR Lab while we are getting real-time feedback from the users. We choose this method among unmoderated remote usability testing method because of the hardware requirements for our project.

- **MYO Arm Band:** An armband that gives us EMG data for tracking of muscle movement to transmit gestures made by the user to Unity. We will use MYO arm band at second step of the project.

III. Problem Statement

Project Scope

During the production process for personal bionic protheses for amputees there are problems for the rehabilitation and adjustment time. Our project scope is to reduce this time. The project was part of another project by Can Bora Sezer and Prof. Erhan Öztop that aims seeing how amputees can adopt to having a virtual arm and training them in Virtual Reality which can affect the time of adjustment process for their bionic prostheses. Our part was the integration of Leap Motion for hand and finger tracking for arm training and creating realistic virtual reality environment and testing the efficiency of integrated leap motion hand and finger tracking.

Engineering Problem

The engineering problem was integration of leap motion hand tracking on virtual reality environment and using it to collect data. The project topic suggested by Prof. Erhan Öztop and Bora Sezer which is about creating virtual arm for amputees to reduce the time spend for the rehabilitation and production of real bionic protheses. Then it detailed with collecting hand tracking data by using leap motion at realistic physical environment at virtual reality. Additionally, creating realistic test scene that includes some physical activities or games to test the integrated leap motion on HTC Vive in an efficient way.

Assumptions

The first and most significant assumption is that unity will continue to support virtual reality development tools named OpenVR.

Second assumption is that the minimum hardware requirements to test the project will be provided.

Third assumption is that Valve will support SteamVR and additionally Leap Motion drivers and SDK's will be supported.

On the other hand, there were some assumptions for support of Leap Motion SDK because they are not providing long term support and current SDK not working properly for this project. However, edited Leap Motion SDK solved problems as expected and is completely operational.

Constraints

For the project, there are multiple constraints.

The most significant constraint is that all hardware requirements which are HTC Vive pro and Leap Motion must work properly and bought before usage.

The second constraints minimum system requirement must be provided for the project which is a graphics card that can run virtual reality applications.

IV. Solution Approach

DESIGN DECISIONS

By the end of the problems statement, a scenario that user can integrate object with real time physics should be created for this project. Project mainly focuses on hand gestures and physics; therefore, hand should be tracked in both position and orientation. First design decision is to track hand and especially fingers by using a method called Hand position tracking by capturing position of the palm (forearm) using depth camera. On the other hand, project also focuses the reality and environments impact on the user's reality. Virtual Reality solutions are best options that provide mixture of reality on computer-based systems. One of the Virtual Reality techniques, immersive system decided to be implemented into the project. Head mounted display devices should be selected in order to create an immersive system in virtual reality.

Combination of two design decision which is using hand tracking in an immersive system enables the project creates realistic environment which is for training hand gesture of the users.

TOOLS & TECHNIQUES

In this section, solution approach comparison and explanation will be examined. By dividing into two sections as used tools and used techniques helps to clarify solution approach more effectively.

Part 1: Used Techniques

For this project, two main technique used. These techniques are finger tracking for recognition of user interactions and Immersive System technique with Simulation Based Virtual Reality.

In Immersive Systems (IS), the user immerses oneself in a room which viewer stand in virtual reality (VR). "Immersive" VR system equipped with a Head Mounted Display mostly called HMD. These king of display masks provide high frame rate (HFR) visual data and audio. In addition to Immersive System, Simulation Based Virtual Reality method developed by intending to visualize human action in a given scenario as a simulation. [1]

In the field of gesture recognition and image processing, finger tracking is the key method to reduce the controller which provide more realistic integrations between Virtual Reality and the user. Hand position tracking by capturing position of the palm (forearm) using depth camera method used to track in real time the position in 3D and the orientation in 2D of the fingers. That method helped to create real time hand object in 3D Virtual Reality environment.

Part 2: Used Tools

After deciding techniques will be used for the project, demand of tools appeared in a two section. For the first section, virtual reality head mounted display (HMD) must be implemented to the project in order to maintain simulation based virtual reality method. In addition, hand tracking tool should be selected carefully as working with HMD.

Firstly, HTC Vive Pro headset selected as displaying tool in order to other headset such as Oculus Rift and HTC Vive which are provided by OzU VR Lab, due to the fact that Vive Pro provides higher resolution and higher frame rates. In implementation process, a software named OpenVR which enables to develop virtual reality headset devices is used for communicating with HMD set. OpenVR created and supported by company named Valve for supporting their application programming interface named SteamVR. In order to reach data from HMD devices, OpenVR software should be used; therefore, OpenVR and SteamVR are free to use by developing virtual reality applications.

Secondly, Leap motion device is selected as providing solution to the hand position need. In order to selecting Leap Motion, HTC Vive Pro's embedded depth camera can be used for this mission. However, range of the cameras of Vive Pro covers lower area than

Leap Motion’s and Leap Motion provides higher frame rates. Leap Motion provides data in real time positioning in 3D and orientation in 2D which can be used for any rigged hand model. Leap Motion also afford no charge to develop applications, uses free to develop.

In addition to those tools, there must be an engine that visualize virtual reality environment. The engine should be worked with both HTC Vive Pro and Leap Motion. On the HTC devices providing developing support almost every popular engine. However, Leap Motion restricted their support only Unreal Engine and Unity. Therefore, Unity selected as game engine that all system will be build on due to the fact that user friendly interfaces, efficient and stabilized working process with HTC Vive Pro and developers’ know-how on Unity game engine.

FEASIBILITIES

Feasibility of implementing the project can be examined under three part which are technical feasibility to explain used techniques and tools are enough to make it work, operational feasibility is to understand project is enough to solve the problem and financial feasibility is to examine the project is juicy.

Part 1: Technical Feasibility

Technical feasibility examination examines project expectation and how they are covered. For the effectiveness of the virtual reality, Unity’s graphic engine’s power satisfied the need of realistic environment. In addition to that, Unity’s Physic Engine worked well to provide the sensitivity that the user feels their visualized hand physics in virtual reality. Secondly, Leap Motion device is worked properly. However, Leap Motion SDK is not enough to maintain the project because of many versions mismatch error; therefore, Leap Motion’s open source SDK edited to work on this project properly. To conclude, all methods and tools selected to be used in this project implemented well and they are working properly.

Part 2: Operational Feasibility

The system to solve the stated problem working operational and solves the problem as expected in the part that project designed. Unity’s and OpenVR software provide long term support (LTS). The only anxiety was the support of Leap Motion SDK because they are not providing long term support and current SDK not working properly for this project. However, edited Leap Motion SDK solved problems as expected and is completely operational.

Part 3: Financial Feasibility

For the usage requires one-time purchased equipment which are Leap Motion device, HTC Vive Pro Virtual Reality glasses and computer that provides enough computational power to maintain these devices. For the personal purchasing, system seems not feasible but fairly enough to maintain by companies and laboratories.

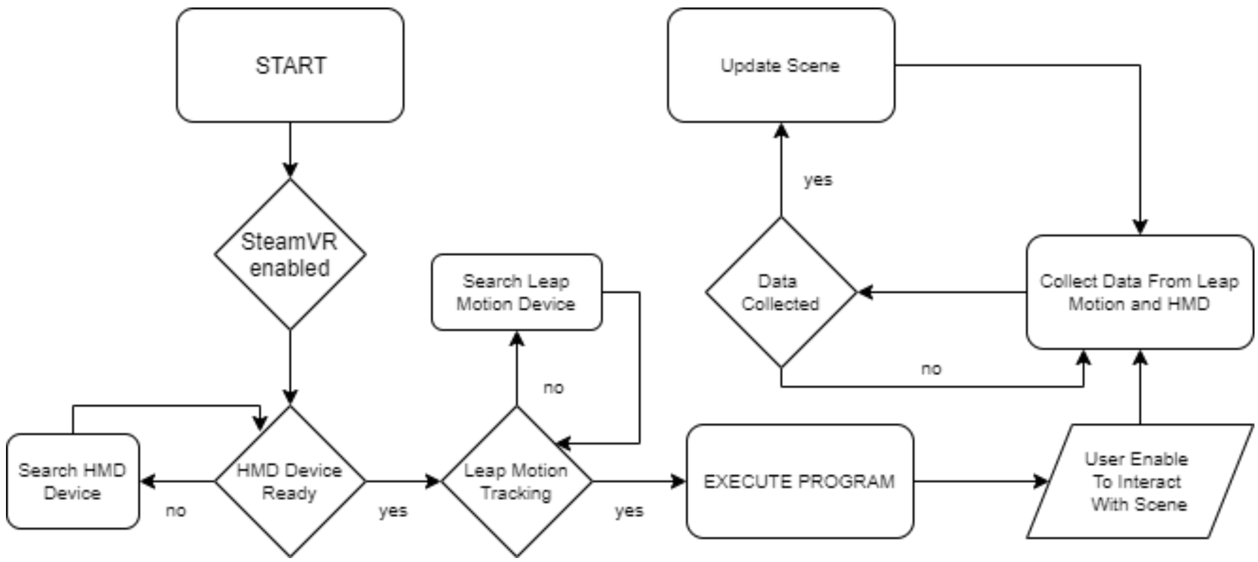
KNOWLEDGE AND SKILL SET

Producing and maintaining that type of project, developer should have a skill set that covers both software and hardware issues. In order to develop software on the Unity or another game engine platform, developers should understand object-oriented programing paradigm and have background on C++ and C# programming languages. In addition to that, developers should be familiar to hardware which use communication techniques and image and laser processing; therefore, computer graphics and vision classes provides very useful knowledge to develop these types of projects. Lastly, maintaining term long projects, at least one of the developers should have knowledge on Software Engineering area. These skill sets and knowledge can be maintained by taking class of CS 102 (Object-Oriented Programming), CS 320 (Software Engineering), CS 434 (Advanced OOP), CS 442 (Computer Graphics) and CS 423 (Computer Vision) classes in Özyeğin University.

ENGINEERING STANDARDS

The purpose of using engineering standards is to ensure the minimum performance and maximum benefit; therefore, developing in Unity requires to follow the standard of both Unity3D programming and C# Coding Conventions. [2] In addition to these standards, developers should follow to standard of using SDKs which are Leap Motion SDK and OpenVR SDK.

FLOW CHART



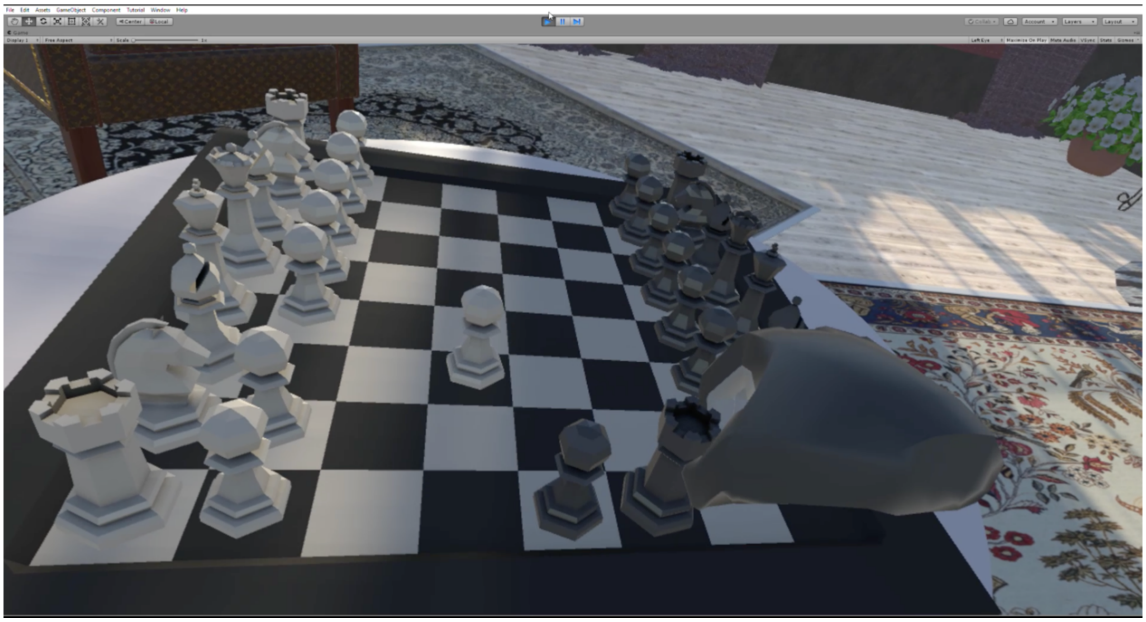
V. Result and Discussion

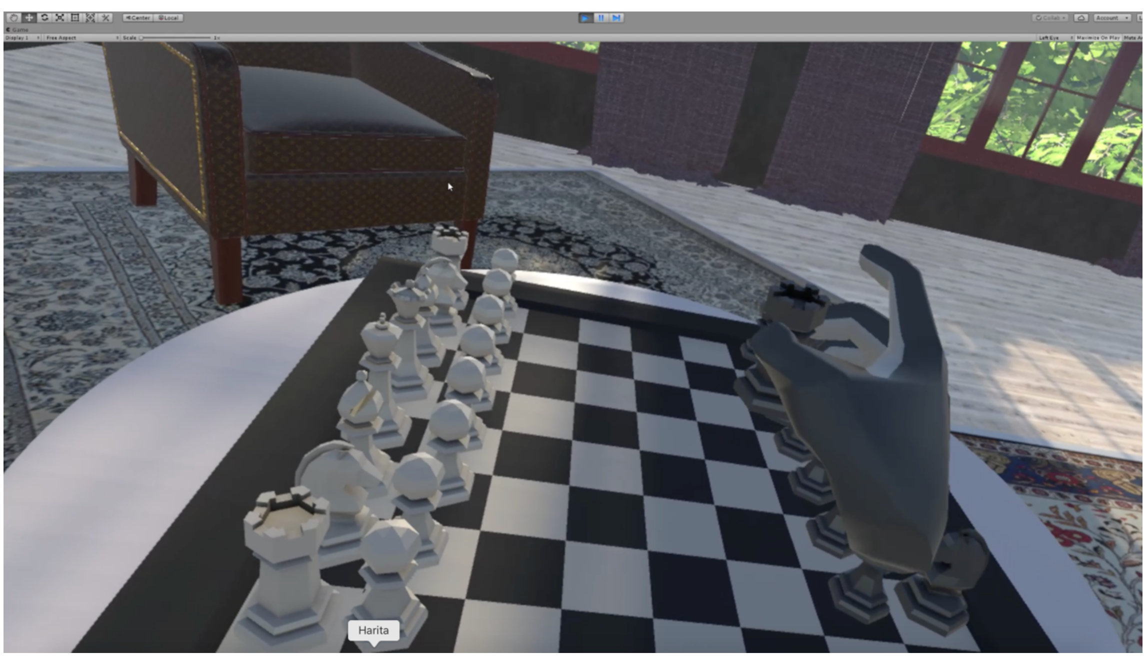
As a result of the process, the integration of Leap Motion on HTC Vive completed and realistic virtual reality environment that includes two activities for testing completed. Hand and fingers tracking work correctly at our system but requires satisfying hardware components to increase the frame per second. The first activity for testing the leap motion hand tracking and its physics is a realistic and working piano that is modelled with Blender. The second activity is an interactable chess board. Additionally, a simple house and its components added to create a realistic environment. The screen shots of the scene can be found at appendix. (NUMBER)

We have tested our project on 10 different people who are not amputees. As a result of the test, without using any device with hands, they are satisfied with the level of reality, although there was not any feedback taken from any device. However, for the movement, there were some difficulties without using HTC Vive controllers.

During the project there were some limitations faced which are the SDK problems for the Leap Motion. The SDK edited to use properly. Additionally, the Leap Motion device we used did not work at the beginning process of project and could not be used until the repairing process ends. There was limitation to use other rigged hand models because of the SDK of Leap motion.

There are some example screenshots taken from our project that can be seen below. The screenshots include the physical chess board and piano to test the leap motion integration on unity.






Left Eye
Maximize On Play
Mute Audio
VSync
Stats
Gizmos


File Edit Assets GameObject Component Tutorial Window Help
Launchpad

VI. Related Work

In this section, related work comparison and explanation will be examined. By dividing into two sections as related techniques and related projects helps to clarify solution approach more effectively.

Part 1: Related Techniques

Using HMD devices to create an immersive system in virtual reality is very common approach. In order to other techniques, immersive system is very efficient to immerse the users' personal viewpoint inside the virtual world; therefore, Virtual Reality game sector focuses on immersive system modeled projects. Many virtual reality games such as Arizona Sunshine and VR Lab can be a good example of how this type of virtual reality implemented.

Part 2: Related Projects

Combination of immersive system and hand position tracking by capturing position of the palm (forearm) using depth camera techniques is also scope of company who produces Leap Motion. They focused on game sector and Leap Motion has own game archive which includes games that have this combination. However, Leap Motion stopped to maintain their games and their games removed from the stores due to an unknown reason. On the other hand, Leap Motion SDK still open to develop freely and there are couples of developers who are focused on same combination of two techniques. There is a short YouTube [3] video where a developer explains his piano training application which uses Leap Motion and Oculus Rift. That project provided an idea that piano mechanics is very useful to understand the efficiency of hand and finger physics; therefore, new piano created for test scene with inspiration of this project.

VII. Conclusion and Future Works

Achievements

By the end of the first part of the project we achieved all the goals stated at the beginning. The objectives we achieved are to implement hand and finger tracking and physics into the game engine as a tool by using Leap Motion, to create a realistic virtual reality environment for the training and to analyze the effectiveness of this environment with user testing.

Impacts

The social impact of the project can be described with the contribution of the project to health sector and psychological researches for the amputees. The project can decrease the time of psychological recovery process for the amputees and can decrease time of adjustment process for the real bionic prostheses. For the economic impact of the project, this project can improve the developing process of the real bionic prostheses due to testing process on virtual reality environment and by using personal data gathered at virtual reality.

Ethics

The ethical issue for the project is the attractiveness of the immersive world created with virtual reality. The training process for the amputee may away from the real world. However, some psychologists use the virtual reality at their therapy process for the people who have a fear of heights. So that, if the training process is carried out in consultation with psychologists and under their supervision, the ethical problem may disappear. [4] Since the project not finalized completely, it is not tested by the amputees for the ethical issue.

Future Work

For the future work, we will implement a machine learning algorithm using the data gathered from leap motion. We are planning to increase the special movements detected by the MYO arm band by using leap motion tracking. Thus, we will do personal train for the MYO arm band by using the machine learning. At default settings MYO arm band SDK can detect five different moves. We will try to increase the number of moves detected with machine learning algorithm.

Finally, we are planning to produce a simple bionic prosthetic that works with trained MYO arm band. After that, we will test it with the people with disabled arms if we solve the ethical issue for the process.

Acknowledgements

This project was supported by OzU VR Lab and the devices used in the project provided by OzU VR Lab. We are thankful for Can Bora Sezer who is the lab head focused on Virtual Reality and Immersive Design.

We are thankful for Associate Professor Furkan Kıraç for assistance provided us from beginning to end of semester.

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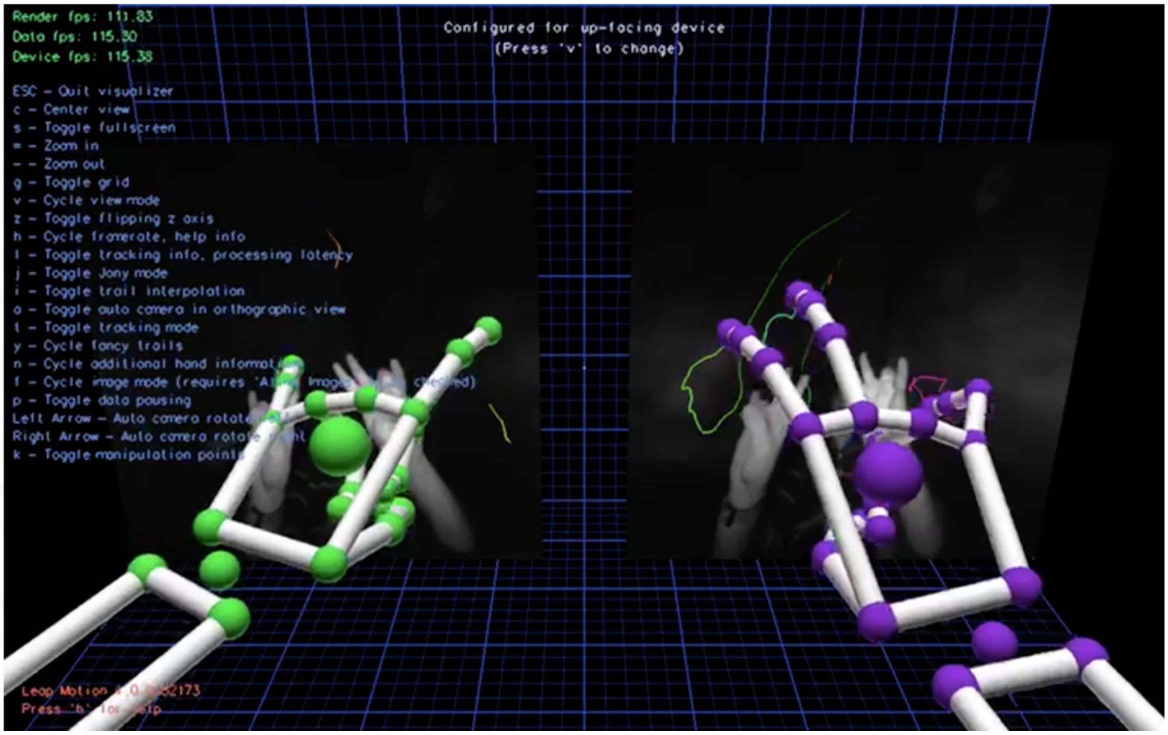
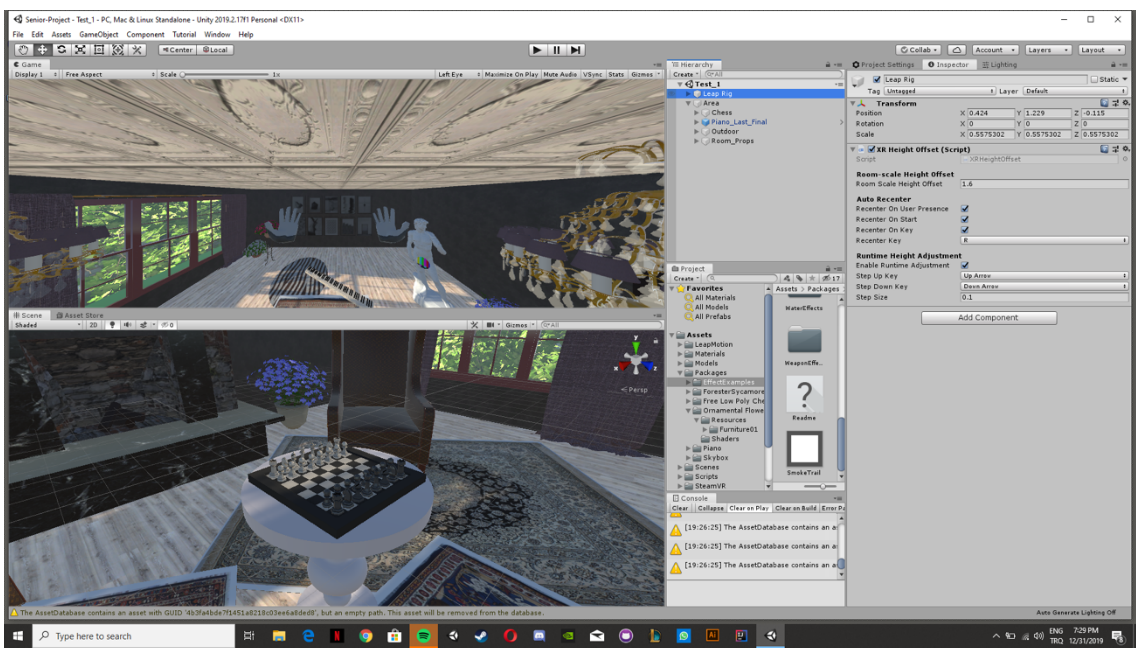
[7] P. Ann M. Simon, «Patient training for functional use of pattern recognition– controlled prostheses,» pp. 56-64, April 2012.

Appendix

1) Leap Motion Visualizer



2) Unity Workspace



3) Working Environment