3D Billiard Game with Leap Motion™ Controller; a Study in Hand-Gesture Human Computer Interaction & Virtual Reality

User Interfaces Course Project Proposal
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Preface

Recently research of innovative ways of human-computer interaction and the study of virtual reality have become two of the most thriving branches of contemporary Computer Science. As a result of recent developments in these fields “Leap Motion” controller, a hand-gesture input device, has become commercially available and quickly acquired a large developer community. [1], [2] study performance and usability of Leap Motion device and the design challenges of using hand gestures in general. Building upon these researches, we propose a project to design and implement a 3D Billiard game which incorporates Leap Motion controller for input, and then to evaluate the user experience.

In the first segment (Introduction), after a brief glance at the previous works on Leap Motion device evaluation, we demonstrate the purpose of this research project, then in second segment (Project Definition) a short description of the project is presented. Later in third segment (Technological Requirements) the logic of our choice of technology is examined.

In fourth section (Risks & Challenges) we go through the critical aspects of the project. Later in fifth section (Evaluation) we'll define a set of tests for evaluating the user experience. Finally in the last section we present a timetable for project’s execution.

“Appendix I” contains some useful information about the proposal supporting documents and demos.

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1. Introduction & Motivation

In the long history of Human Computer Interaction (HCI) field, despite the very many innovative interfaces that have been proposed, no input interface has yet practically superseded the simple combination of mouse and keyboard in performance and data transfer capacity.

These two devices, however, aren't the natural means of communication and interaction of human beings. People communicate seamlessly, by speaking to each other and control their surrounding environment using their hands. Keyboard and mouse are the best available substitutes, but that don't even get close to the data transfer rate of speaking or controlling tools using hands. The amount of information transferred through speaking or the amount of information transferred to a musical instrument through the hands of a musician vastly exceeds their digital counterparts. This leads us to research in the field of HCI, to find ways to enable computers to interact with people more naturally. One of these ways is to communicate and control computers using hand movement and gestures.

[2] specifically studies hand gesture input using Leap Motion controller (a hand gesture input device) as a substitute for pointing devices in WIMP environments (Windows, Icons, Menus and Pointers). After extensive research it concludes that Leap Motion controller (LMC) is not a good replacement for mouse as a pointing device. However, we believe that a better study would be to evaluate LMC not a as a pointing device, but as a device to interact with 3D Objects.

If the goal is to achieve a more natural human computer interaction, then WIMP environments which are exclusively designed for use with mouse and keyboard aren't the best choices. A better choice will be to evaluate the hand gesture input device comparing it to the way we use are hands to grab, move, control and throw physical objects.

This is where our research enters the field of Virtual Reality (VR). In VR field, computer scientists try to imitate physical presences in a computer-simulated environment. We suggest that the extent of usefulness of a hand gesture interaction can be explored more thoroughly when it is examined in virtual 3D environments.

In the following section we propose the implementation of a simple 3D game, to be used to assess the capabilities of hand gesture based input devices and gesture based interactions.

2. Project Definition

Considering all above, to be able to evaluate hand gesture based human computer interaction, we decided to test it in a 3D virtual environment where we can simulate physical interaction with simple objects. The game of Billiard is a good example of this kind of physical interaction. Therefore, we propose to implement 3D Billiard Game of 8Ball, in which user uses his/her hands to shoot the ball and play the game. Time permitting, multiple evaluation scenarios will be implemented to measure the performance and accuracy of this style of interaction. Finally considering the results of the evaluations, conclusions and suggestions will be made to improve the user experience.

3. Technological Requirements

To achieve above mentioned goal, first, we need to capture and model the hand gesture digitally, then incorporate said model to control a 3D simulated game of Billiard.

3.2. Hand Gesture Input Devices

There are three main solutions for capturing hand gestures:

1- To use obstructing devices like sensor-attached gloves to capture and measure the movement of hand and fingers muscles mechanically. These devices are very accurate; however, they cost a lot and obstruct the free movement of the hand.

2- To use vision based hand gesture input devices. These devices aren't very accurate, but a variation of them which uses infrared lamps, compensates for the inaccuracy and increases the performance to an acceptable level.

The vision of infrared hand gesture input device has a limited depth, which helps minimizing the noise and the hands are recognized by the device much easier. The other benefit of these devices is that since the camera on these devices is only sensitive to the infrared ray, the information of the distance of the object will be kept in the input signal so it creates a better hand model.

Leap Motion Controller (LMC), is an infrared sensitive hand gesture input device which has become available commercially very recently. LMC driver, not only creates the hand 3D model, but also is equipped with intelligent error correction algorithms, to predict the state of the hidden side of the hands.

[3], [4] calculate the precision of LMC to be within 0.01mm which can't possibly be true, but [1] and [2] which independently calculate get a result between 0.2 to 1.2mm averaging 0.7mm, which is more realistic and still very impressive.

Considering above reasons and after a thorough comparison of different technologies' performance, cost and availability, we chose and acquired the LMC device for this project.

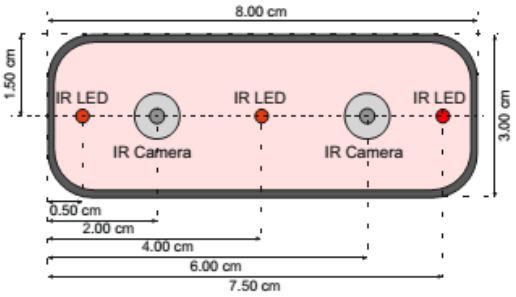


Figure 1. Leap Motion Controller Schematic[1]

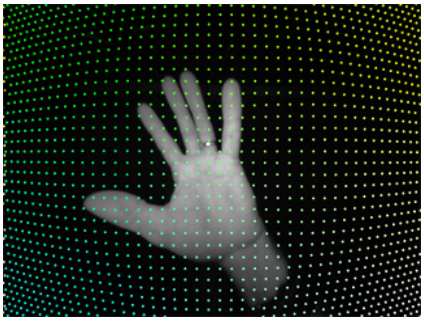


Figure 2. LMC Camera Image[4]

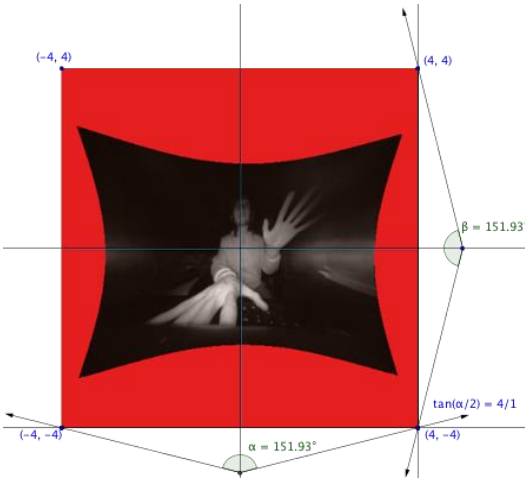


Figure 3. LMC Camera Image[4]

3.2 3D Engine & Physics Engine

3D engines are software libraries that enable access to graphics card for modeling and rendering 3D objects, to be used by various programming languages. Physics engines are software libraries to help model 3D objects' physical interactions. Currently we are considering multiple options for this purpose and we'll finalize the selection in the following week.

The attachments of this proposal includes a simple open-source application called LeapPhysicsSandbox[6] developed using C# and Unity which lets user move a 3D box or starting a domino using LMC. A recording of our first experiment with LMC and LeapPhysicsSandbox is included in attachments, too.

4. Risks & Challenges

With the optical hand gesture recognition devices, the first limitation is status of the part of the hand that is not visible to the camera. This, and the response time of the hand 3D model can negatively affect the user experience. Proper cautions and design choices must be made to compensate for this shortcoming, to deliver a functioning game/application.

Another challenge of this project is that we are planning to only use the hand gestures interactions to control the whole game. This can include navigation through the menus and configuration of the settings of the game. The ease of use and overall design of these menus and navigations also is a user interface design challenge.

5. Evaluation

Time permitting, various evaluation scenarios will be executed to study LMC performance and user experience. Some examples of these scenarios are:

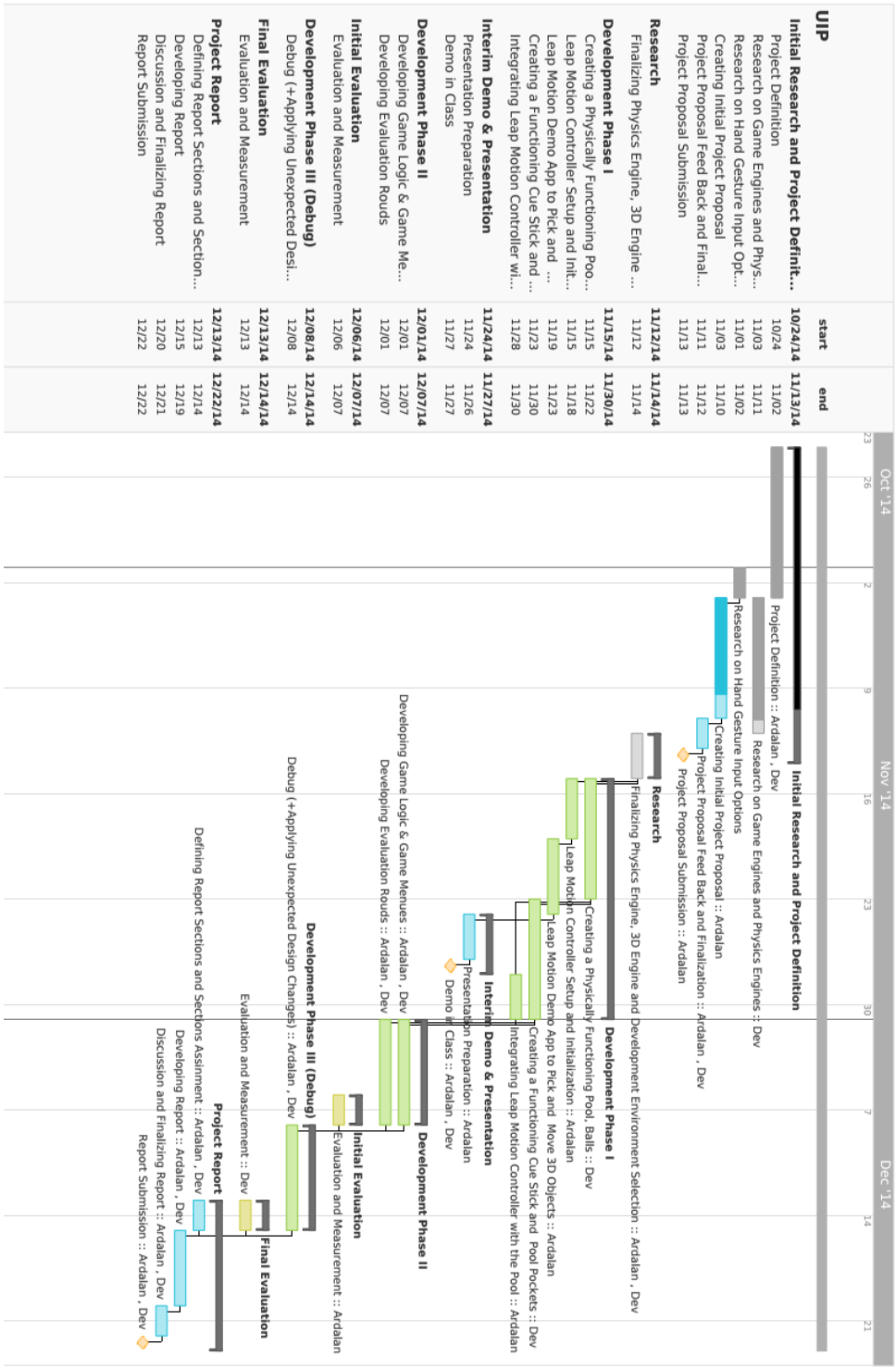
1- To measure the capacity of LMC interface in successfully communicating the intention of the user to the computer, several targets will be put on the pool. Then, randomly a target is selected and user will be asked to shoot the ball towards it. The hit and miss rates will be calculated. This test can measure accuracy and considering the distribution of hits and misses we can determine if our input device is biased in detecting some hand orientations better than others.

2- To be able to compare the interaction experience between the LMC and real pool game, user can be asked to pick, move or shoot the balls, placed similarly in the application and a real pool table. The comparison of outcomes, and the time spent to accomplish a set of tasks in these two environments can produce a reliable measure of how natural and trivial this style of human interaction is.

3- Finally, survey of expressed user experience can be executed to evaluate users' feelings towards this user interface.

7. Project Timetable

The following is the project execution timetable and the breakdown of the project tasks:



APPENDIX I

Proposal Attachments Directory Listing

/Demo	
/Demo/Images	
/Demo/Images/IMG_866...881.JPG	Screenshots of our first experiments with LMC.
/Demo/Sample Application	LeapPhysicsSandbox[6] developed by Pohung Chen and publically available on internet. This application examines the physical interaction of Leap Motion controlled objects with a box and a domino game.
/Demo/Videos	
/Demo/Videos/IMG_877.MOV	The video of our first experiment using LeapPhysicsSandbox[6] and LMC
/Documents	
/Documents/3D Billiard Game with Leap MotionTM Controlle(Head).docx	Proposal Source Files
/Documents/3D Billiard Game with Leap MotionTM Controlle.docx	Proposal Source Files
/Document/Timetable.pdf	Project Gantt Chart
/References	
/References/DissTemp.pdf	[2]
/References/sensors-13-06380.pdf	[1]
/Proposal.pdf	Project Proposal (This File)
/README.txt	README file containing the same information as appendix I

REFERENCES

[1] Weichert, Frank, et al. "Analysis of the accuracy and robustness of the leap motion controller." *Sensors* 13.5 (2013): 6380-6393.

[2] Seixas, M. C. B. (2014). Leap Motion for WIMP based interfaces.

[3] Motion, L. (2014). Leap Motion Developers Portal.

[4] Motion, L. (2012). Leap Motion Software Development Kit.

[5] Spiegelmock, M. (2013). *Leap Motion Development Essentials*. Packt Publishing Ltd.

[6] Chen, P. (2013, June 19). Leap Physics Sandbox. Retrieved November 11, 2014, from https://bitbucket.org/pohung/leapphysicssandbox/overview