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Gesture Based Interaction in Immersive Virtual Reality

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Abstract— Recent development in virtual reality (VR) interaction with 3D camera and sensors like kinect, range camera, leap motion controller etc., has enabled opportunity in development of human computer interaction (HCI) application. Hand gesture is one of the popular ways that people use to interact with the computer. Even automatic hand gesture recognition appears as a suitable means for interacting with virtual reality systems. This paper focuses on the study and analysis of the application based on gesture interaction technology in virtual reality. Customizing gestures for pointing, grabbing, zoom in/out, swap were defined and implemented in unity 3D with leap motion SDK. The effectiveness of the hand gesture was analyzed through recording user experience and questionnaire.

Keywords* — *Hand Gesture; Leap Motion Controller; VR Environment

1. Introduction

Recent developments in virtual reality supporting headsets devices like Oculus rift/Go, HTC Vive and Microsoft HoloLens, immersive virtual reality has been applied in various fields like, gamming, entertainment industry, virtualization of historical monuments, in the field of data visualization and also in the field of medical like rehabilitation in general, and of brain damage treatment in particular [1-3] providing an immersive experience to users. However, studies on multimodality that enhances immersion is yet to be explored in depth, the immersive experience to the user interaction methods and user-centered interfaces that satisfy higher levels of immersion and reality are still required to be enhanced in order to increase the user's presence. An interaction-based feedback system and experience environment that can satisfy the senses of hearing and touch are important. In this regard, virtual reality technology combines with hardware systems such as treadmills and virtual reality gloves, along with advances in head mounted displays, including the Oculus Rift CV1 / GO, HTC Vive, and Samsung Odyssey. The application studies such as user interface in immersive virtual reality that can directly interact with virtual environment and realistic control of objects and haptic feedback based on it have been conducted from various viewpoints until now [4-6]. In addition, recent development in Leap Motion hand tracking sensor [7] has enabled us to precisely track and enhance VR interaction experience. Leap motion enabled VR allowing the user to explore, interact and manipulate scene objects as in the real world. In this paper we have proposed a methodology that combines leap motion with oculus rift head mounted set, we design a hand motion sensor-based interaction method that accurately detects and tracks hand movements without wearing additional equipment, and responds to various motions and gestures to virtual hands. The dedicated controller provided with the VR head mounted device (HMD) to design a controller-based interaction method that maps the keys of the controller with the actual hand, providing enhanced immersion that feels like a real hand. The paper is organized as follows: section 2 provides related work reviewed in the study. Section 3 provides proposed methodology. Section 4 presents result and discussions. Section 5 provides conclusion.

2. Related Work

The purpose of contact-free 3D human-computer interaction is to enhance the presence by providing the user with a realistic interaction with the environment or objects provided by immersive virtual reality by utilizing various senses of the human body such as vision, hearing, and touch. In [8-10] supports interaction application technology using gaze, gestures, etc. to enable users to easily control movements, express behaviors, and realistically feedback physical reactions occurring in a wide range of virtual environments. Recently, Oculus Touch and HTC Vive's controller devices are used to support accurate interactions as in [11] has proposed grasping system, which supporting real-time interaction in virtual environment, and also in [12, 13] virtual object is controlled and interacted on mobile platform using gaze-based hand interaction also they have analyzed gestures and movements by capturing hands through markers to reflect the behavior more directly in the virtual environment [14]. Interaction using haptic devices is also studied [15], where haptic interaction system calculates the distance of hand movement and measures the force generated during the object control process to feedback the experience such as heaviness and the sense of touch [16-18]. Various interactive studies are conducted in relation to the data glove, a representative tactile interface to the hand, the system also provided physical feedback along with the measurement of force, using various mechanisms such as a system that combines a wire drive and a manual spring [19, 20]. Recently, there are also active researches on analyzing factors that can improve presence in terms of interaction [23, 24]. Therefore, we propose an interactive method that optimizes the interface through input methods that are more

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accessible and familiar from the user's point of view, using existing popular technologies. It is also important to conduct an experiment to analyze the process and the extent to which the presence changes. From this point of view, this paper aims to analyze the detailed factors that affect the presence through the interaction and the interface that can increase the user's immersion in the minimal experience environment.

3. Proposed Methodology

In proposed methodology, the sensor based interaction approach handle inputs freely using hands without additional equipment in VR environment. In order to interact with hands directly, it is necessary to accurately detect and track hand movements, and classify and recognize motions and gestures based on them. In our proposed system we use leap motion equipment, which is popularly used in the VR interaction research. Previously, studies on the optical hand and surface markers worn on the hand and tracking them to map the behavior of the virtual hand model [23-24] have been conducted. When approaching real-world applicability, we take advantage of the leap motion equipment that provides a library that can be developed on the game engine at a lower cost. The leap motion sensor is an input processing device consisting of two infrared cameras: an infrared recognition module and an infrared light source (LED). It has a small size of 1.27mm × 80mm and can be easily used by attaching it to the front surface of virtual reality HMD such as Oculus rift, HTC VIVE, etc. When the user moves the hand in front of the infrared sensor, the movement is recognized in units of finger joints and accurately corresponds to the hand of the virtual environment. Fig. 1 shows how the leap motion development tool integrates with the Unity 3D engine to create a development environment.

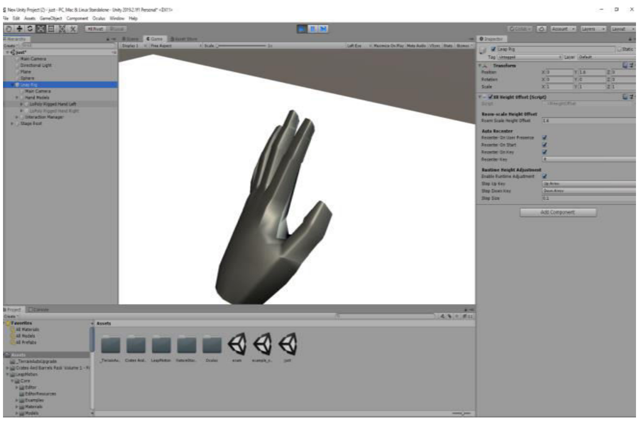


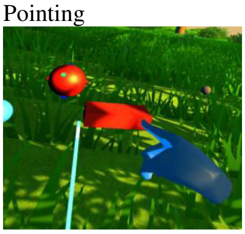
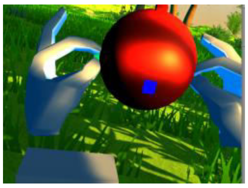
Fig. 1: Leap motion interface integration with unity 3D

It is possible to control and synchronize a three-dimensional hand joint model corresponding to the recognized hand through the leap recognition space. In addition, the functions provided by the leap motion development tool can be used to check the current state of the hand and finger, thereby defining the gesture.

3.1 User Interaction with VR Environment

We have defined four gestures to interact with any of VR based applications. The Table 1 gives the detail of the gesture and their functionality.

Table 1. Customizing different hand gesturesto interact with VR application

Gesture	Function
Pointing 	Pointing gesture is used to point an 3D object to perform a particular task for example change the color of object or menu interaction
Grasping 	It is used to grasp an object and interact with it like rotate an object, change the position of the object.
Zoom in/out 	The zoom in gesture increases the size of the object. The zoom out gesture reduces the size of the object
Swap 	Swap gesture move the object

The recognized hand model information (hand) is stored using the functions provided in interaction engine by the leap motion development tool. Then, the actions such as grasping, opening, pointing to an object and zooming and zooming out the object defined. Algorithm 1 shows how the hand model is stored and interaction is initiated. First, the hand state is detected from hand model function as shown in Algorithm 1, hand model returns three value one is hand state which represent whether the user has

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opened or closed his hands and then the next value is state_point which indicates that the user is pointing and if the user has extended two fingers then it is represented by state_zoom

Table 2. Algorithm1

Hand_Model Algorithm to detect the state of the hand

1. Hand H= HandModel.GetLeapHand()
2. Number_of_fingers =0
3. if H.IsRight == true then
4. for i=0 to 4 do
5. if H.Fingers[i].IsExtended == true then
6. Number_of_fingers ++
7. end if
8. end for
9. if Number_of_fingers == 0 then
10. state_grasp =true
11. else if H.Fingers[1].IsExtended ==true and Number_of_fingers=2 then
12. state_Zoom= true
13. else if H.Fingers[1].IsExtended ==true and Number_of_fingers=1 then
14. State_point= true
15. end else if
16. end else if
17. end if

Once the hand state is detected using hand interaction function corresponding actions are performed Algorithm 2 gives the detail of hand interaction procedure.

Table 3. Algorithm 2

Hand_Interaction Algorithm to interact with hand model

1. state_grasp = grasp the left/right
2. state_point =point to the left/right hand.
3. state_zoom= zoom
4. Procedure Hand_interaction (hand_state , hand_point, hand_zoom)
5. grasp_count = check grasping state.
6. if state_grasp = = true then
7. if grasp_count == false then
8. initiate grasp process
9. grasp_count = true
10. end if
11. else if state_point == true then
12. perform pointing action.
13. else if state_zoom == true then
14. Perform zoom action.
15. else
16. if contgrasp == true then
17. perform dropping (opening) action
18. endif
19. endif
20. end procedure.

4. Result and Discussion

Experimental virtual reality application is created for the purpose of analyzing whether user's hands-based actions in the immersive virtual reality are convenient and immersive at the same time through the two interactions proposed for the comparative experiment on the presence of the hand-based interface Fig. 2 is the scene of the experimental application produced in this study. It consists of the interaction process using the actions like picking the object, pointing towards to the object, etc. In order to analyze the presence in the interaction using hands more accurately by presenting a realistic experimental environment in the experience environment called virtual reality, it is composed of some basic 3D objects rather than an application such as a game.

Fig. 2: Experimental testbed interface in Unity 3D for sensor based interaction

The VR application is build and tested on Unity 3D. The PC environment used for the interface implementation and experiment was equipped with Intel Core i7-8700, 32GB RAM, and Quadro P5000 GPU. In experiment we have used the Oculus rift HMD and its dedicated controller, Oculus Touch, to support the virtual reality experience. Fig. 3 shows the environment for experiencing virtual reality through two interactions suggested in this study.

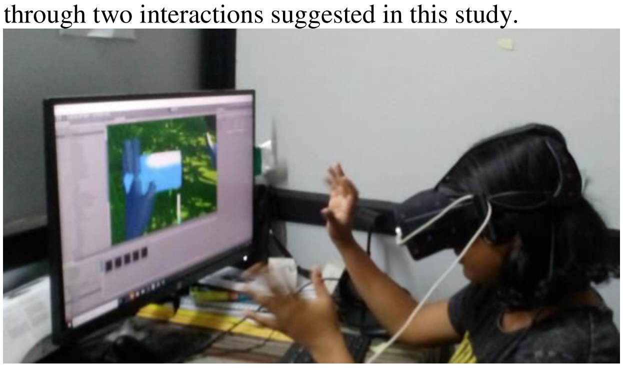

Fig. 3: Sensor based interaction with VR environment using leap motion and oculus rift

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Sitting or standing in a standard sized space in our experiment we have used 3 X 3 m, it was a comfortable experience. The hand motion sensor based interaction recognizes the hand through the leap motion sensor attached to the front of the HMD. Controller-based interactions are set up to hold a dedicated controller in hand.

4.1. Discussions

We have analyzed the interaction experience of the user by conducting the survey, while creating questionnaire for survey we kept all the factors that has impact on the interaction experience and included in the form of questions. Three main categories: finger movement experience, interaction experience and hand motion experience we focused while survey. A total 22 participates with different age group were considered. Ten people had VR experience before and others were new to VR. The proficiency required for manipulating virtual objects in the proposed application can also affect presence, so we asked ten people to first experience hand-based sensor-based interactions and then experience controller-based interactions. For preparing questionnaire we have followed [26] [11].

Table 4. Questionnaire for the study of user interaction experience

Q. No.	Questions
	Hand movement Experience
1	I felt like the virtual hands were like my own hands.
2	I was able to feel the movements of virtual hand as I moved my own hand.
3	I felt as if the movements of the virtual hands were influencing my own movements.
4	I felt as if the virtual hands had no co relation with my hand movements.
	Finger Movement experience
5	I was able to move virtual fingers as I intended to.
6	Virtual Fingers interacted with the objects as per my intention
7	I felt finger movement was not real.
	Interaction Experience
8	I felt like I was grabbing the object as I intended to.
9	I found hard to reach out to the objects.
10	I felt like finger movement while interaction with objects as if my own hand movements
11	I found difficult to understand the movement of virtual hand.
12	I felt interaction with objects as if it was real.
13	Fingers were properly adapting properly to the different geometries.

These questions followed likert scale: strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree and strongly disagree. The average response of the user is calculated as per following equations.

$$R_{hand\_movement} = \frac{(\sum RQ1 + \sum RQ2) - (\sum RQ3 + \sum RQ4)}{4} \quad (1)$$

$$R_{finger\_movement} = \frac{\sum RQ5 + \sum RQ6 - \sum RQ7}{3} \quad (2)$$

$$R_{interaction} = \frac{(\sum RQ8 + \sum RQ9 + \sum RQ12 + \sum RQ13) - (\sum RQ10 + \sum RQ11)}{6} \quad (3)$$

Where $R_{hand\_movement}$, $R_{finger\_movement}$ and $R_{interaction}$ are the average user response for hand movement, finger movement and interaction experience respectively in VR environment. Finally the overall response$R_{overallresponse}$ from the user is calculated using the following equation

$$R_{overall_{response}} = R_{hand\_movement} + R_{finger\_movement} + R_{interaction} \text{ (Er}$$

The Fig. 4 show user response, for the given questioners for question Q1,Q2,Q6and Q8,Q10 and Q13 user average response is between 1.8 to 2.3 on a point scale of 3,as these questions intended to measure user hand and finger movement experience, thus most of the user were able to experience immersive interaction experience. The Fig. 5 shows the user experience in VR measured for hand movement, finger movement and their interaction with virtual objects. About 78.4% of them were able to move their hand and have immersive experience with hand movement, 31.9% of them were able to move their fingers and 96% of them find it easy to interact with the object like grasping, moving and changing the size of objects.

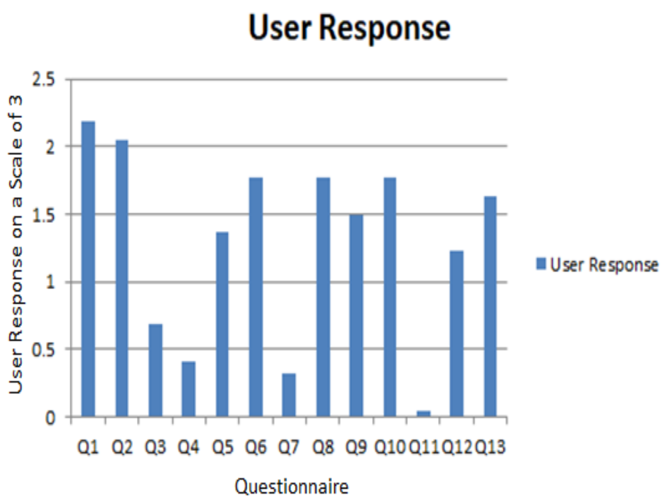

Fig. 4: Graphical representation of User response

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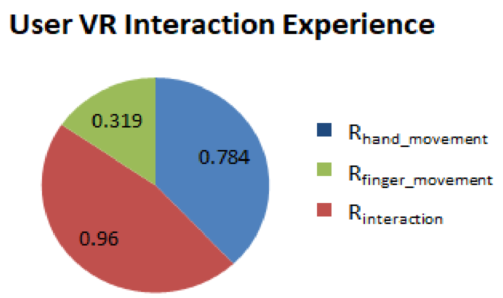

Fig. 5: Graphical representation user VR interaction experience

5. Conclusion

In this paper, we have defined the gestures like pointing, grasping, zoom in/out, swap to interact with the objects in virtual environment using leap motion controller and oculus rift. Further, user interaction experience using gesture with the VR environment was evaluated by recording the user experience through the questioners. Through the user response evaluation we found that about overall 73% of the users were able to interact had an immersive interaction experience in VR environment.

Further, while collecting user response we observed that few users found difficult to reach out object, hence to improve the immersive interaction few more gesture can be added like for moving VR cameras, changing the scene etc.This work can also be extended to extended reality were XR devices like Google Tilt Brush can be used for visualization of VR environment.

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