Natural User Interface for 3D Voxel-based Modeling

Changho Seo[1], Jinseok Seo[2]

[1]Department of Digital Media Engineering, Dong-eui University, Busan, Korea
[2]Division of Digital Contents Technology, Dong-eui University, Busan, Korea

Abstract— *In this study, we propose an interaction method for 3D voxel based modeling in immersive virtual environments. We assumed that all tasks must be NUI (Natural User Interface) based interactions, rather than using conventional input devices like keyboard or mouse. To see the usefulness of our proposed interaction methods, we have created an immersive virtual reality application that can interact with three-dimensional objects using only hands and arms. The modeling process requires interactions for two types of tasks. One group is the menu selection and control tasks, and the other is the manipulation tasks for voxels. We have defined motion interactions that are appropriate for each task so that all actions are possible only with hands and arms. In order to confirm how effective the proposed methods are, we have produced various shapes of 3d objects. Based on the results, we investigated the possibility of NUI based interactions proposed in this study.*

Keywords— *NUI (Natural User Interface), HMD (Head Mounted Display), immersive, 3d modeling.*

I.　INTRODUCTION

With the advent of Oculus Rif in 2012, which uses advanced technology, and the introduction of various virtual reality contents using it, HMD-based immersive virtual reality has received great interest from people. On the other hand, the development of input devices that interact with virtual reality is relatively lagging behind the development of HMD. The contents that appeared in the early days used conventional devices such as keyboards, mice, and game controllers as the interaction devices between users and virtual reality. However, these input devices act as obstacles to the user's immersion into the virtual reality. For this reason, recently, devices that allow more natural interactions are being announced, and in a near future, virtual reality that does not require cumbersome devices is expected to become popular. As a result, if users are free to interact with both arms, the user will feel more immersive and the performance of tasks in virtual environments will be much higher.

Just as it is quite natural nowadays, the GUI (Graphical User Interface) we are using has evolved from the former CLI (Command Line Interface) to the interactive environment using WIMP (Windows, Icon, Menu, Pointer). Moreover, in recent years, the transition to the NUI (Natural User Interface) environment has been progressing gradually due to the development of various virtual reality related technologies. We started this study to prepare for NUI-based computing environment to be unfolded in a near future.

The structure of this paper is as follows. In Chapter 2, we describe the HMD as an immersive VR input device and the NUI-based interactions that are most suitable for a virtual environment. In Chapter 3, we introduce the researches related to this study. In Chapter 4, we describe the HW configuration and software functions of our 3-dimensional voxel-based modeling tool. Chapter 5 explains an example modeling process, and Chapter 6 concludes.

II.　RESEARCH BACKGROUND

2.1　An immersive VR input device: HMD

An immersive device, an HMD, is a type of a display device worn on the head. The user sees images output from two small display panels in front of his eyes. In the past, HMDs used expensive lenses to create realistic screens, the viewing angle was as narrow as 30 to 45 degrees, and the equipment was heavy. As a result, the price was very high, and immersion and realism were not great. However, in recent years, various technologies related to the HMD have been developed to overcome these problems.

One of those devices, Oculus rift, was designed and built by Palmer Luckey. Oculus rift uses distorted images to show wide viewing angles from 95 to 110 degrees. These images are distorted by compressing original images with wide viewing angles, and when viewed through fisheye lenses, distorted images are corrected and wide screens can be seen. In addition, a gyro sensor, an accelerometer, and a magnetometer are also embedded at a very low price compared with the past. Since

then, a variety of popular HMDs have been released, making immersive virtual environments more accessible to the general public, not just professionals.

2.2   User Interface for virtual reality: HMD

When computers first appeared in the world, the way they used computers was through a batch process. Punch cards were used as an input device, and the output device was a line printer only. At this time, however, the term "user interface" was rarely used. The beginning of the real user interface is the CLI (Command Line Interface). The CLI is an environment such as Unix Shell or DOS that responds to commands in text format that must be entered correctly in the system. Since the real-time 2D graphics could be processed and the mouse become popular, GUI-based operating system using WIMP (Windows, Icon, Menu, Pointer) become most. In recent years, however, due to the development of GPU technology, not only 2D but also high-quality 3D graphics can be processed in real time, and with the popularity of HMD, the general public is now able to access virtual reality technologies easily. In this immersive virtual environment, the conventional keyboard and mouse based GUI is not only not able to utilize the advantages of virtual reality but also become a stumbling block to users. Thus, many researchers have recently started to study NUI, a new interactive method.

NUI refers a user interface interacting only with "Natural and Intuitive" actions, rather than indirectly interacting using physical devices. A typical example is interaction through action or voice. The NUI has contact-type methods of operating the device directly in contact with the body, and non-contact methods of operating the device based on recognition technology without direct contact with the body. The contact type includes multi-touch, sensor recognition, brain wave recognition, and non-contact type includes speech recognition and motion recognition.

Multi-touch, which is a typical example of the contact type, is a technique of recognizing a plurality of touch points at the same time, and can perform more various operations than one point recognition. Nowadays, popularized smart phones are capable of flipping, rotating, and zooming operations by using multi touch.

The voice recognition interface, which is one of the non-contact type, is a technology for converting a user's speech into text, analyzing and processing the text. It is developing towards recognizing many vocabulary and natural conversation for all users and increasing recognition rate. Another non-contact approach, motion recognition, recognizes and tracks the user's movement. It replaces the role of the conventional mouse or joystick by utilizing body parts such as hands, arms, and legs. In order to compensate for the problem of occlusion and light interference, which is one of the disadvantages of the approaches using cameras, it is possible to use 2 or more cameras or to compensate date with additional sensors such as gyro sensors and accelerometers.

III.   RELATED WORKS

Recently, as immersive virtual reality devices such as HMD have become popularized, the public interest in NUI has increased very much, but research on NUI has already started for a long time. Among them, there are many researches for utilizing virtual reality or augmented reality contents in various fields. The application areas are so diverse that NUI research has been done for areas such as medicine [1], architecture [2], and VR for the elderly [3].

The console game makers, such as Sony, Nintendo, and Microsoft, have also actively conducted research on sensor devices for NUI and sold sensor devices for games. In [4], the author presents a review of the NUI, and comparisons and analysis results of these sensor devices released by those companies. NUI devices for a variety of applications other than gaming are also being released in recent years. Among them, Leap Motion is widely used in many research institutes including this research. Examples include manipulating complex data in point cloud with a natural motion called "Slice-n-Swipe" [5] and interacting without touching objects by hands in dental surgery [6].

Similar to this study, there are many studies for modeling 3D objects in virtual space by NUI based interaction. A study for interactive sketching in virtual space [7], research for design and manufacturing in VR/AR space [8], and research for prototyping architecture [9] can be found. However, our approach is for the voxel-based modeling, and there are differences in interaction method with the above studies. Voxels were originally designed to simplify very complex objects. As can be seen in [10], the voxel was used to model complex tree shapes.

In [11], the author describes "7 typical characteristics" of NUI. The characteristics include "user-centered," "multi-channel," "inexact," "high bandwidth," "voice-based interaction," "image-based interaction," and "behavior-based interaction." As mentioned in this paper, as technology develops day by day, it is expected that NUI will not inexact and require high bandwidth in a near future.

IV.   3D VOXEL-BASED MODELING TOOL

The application developed in this study is a tool that can model 3D objects using voxels only by the motion of hands and arms in immersive virtual environment. This chapter describes the HW configuration of the system, SW functions for menu and voxel manipulation, and the interactions used.

4.1   Hardware Configuration

We used Oculus DK2 as an output device, and used Leap Motion and Myo as sensor devices for user's motion recognition. Unity Game engine was used as SW development tool. As shown in Fig. 1, Leap Motion sensor was attached to the HMD and 2 Myos were attached to both arms.

Fig. 1: Hardware Configuration of our system (left: Hmd with Myo, center: Leap Motion, right: Myo)

Lip Motion, developed by a venture company in San Francisco, is a sensor that can recognize hand movements precisely, and provides various interaction methods on a desktop PC. Despite its small size of 76mm x 30mm x 12.7mm, it is able to recognize the minute movement of fingers in 8 cubic feet of space. The recognition radius is 150 degrees, and small movement of 0.01mm can be detected. Since the motion is tracked at a speed of 200 FPS, the latency is also very small.

Myo, developed by Thalmic Labs, is an armband-type motion recognition controller. Myo consists of a 3-axis gyroscope, a 3-axis magnetometer, a 3-axis accelerometer, a 9-axis inertial measurement device, and an EMG(electromyography) sensor that responds to the movement of 8 muscles. This device measures and senses the movement of the muscles in an arm and recognizes what user's hands and arms are doing. In addition, it can act as a presentation controller, an RC device manipulator, and a game controller.

4.2   Software Functions and Interactions

The main menu of the proposed Modeling Tool consists of 6 items [Fig. 2 left]. They include "Save," "Load," "Clear," "Colors," "Pictures," "Manipulate." In addition, a button for fixing the menu is located at the upper right of the menu plate. In order to display the main menu in a virtual space, you can pinch with the thumb and index finger of your left hand, and as your hand moves, the menu moves along. In order to select a menu item, touch action is required with the index finger of the right hand.

"Colors" sub-menu allows you to choose the color of the voxel to be created [Fig. 2 center]. There are located three slider bars in this sub-menu. You can change the color by touching and dragging each slider bar with your finger. This sub-menu disappears when you select another menu item from the main menu or select the "Colors" menu again. As with the main menu, all the sub-menus have a "fix" button, so that each sub-menu can be placed at a desired position. Selecting "Pictures" menu shows pictures that can be used as a reference for modeling. Due to the nature of immersive virtual reality, it's a menu made because you cannot see the outside of HMD. "Manipulate" sub-menu allows you to move, reduce or enlarge, and rotate the desired object. To move, select the desired object with the right hand pinch motion and move it. To reduce or enlarge, you should pinch with both hands and then open or narrow both hands. Finally, in order to rotate, you can move your right hand without moving your left hand.
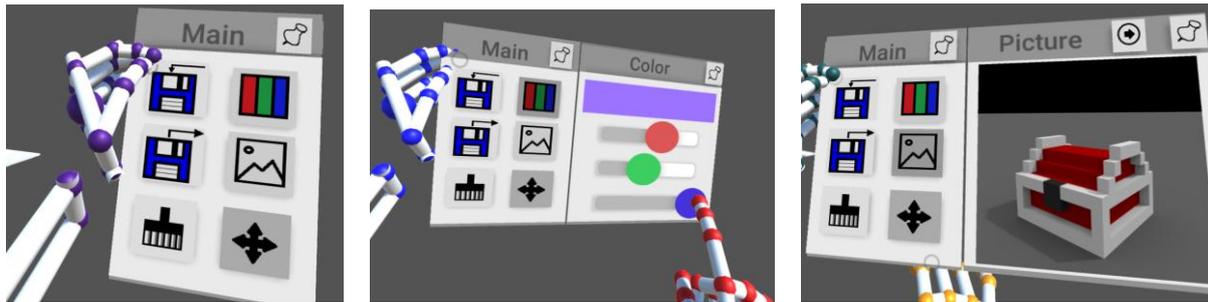
Fig. 2: Menu Operations (left: Main Menu, center: Colors Menu, right: Pictures Menu)

When you create a voxel, if the exact position and the color of the block cannot be confirmed, you will experience many trials and errors. Therefore, we implemented the function to preview the voxel to be generated. You can see the preview voxel by moving the index finger to the position you want to create. However, it is possible to preview only if there is no voxel created beforehand in the position of the index finger. Once you have confirmed that the preview voxel is what you want to create, the voxel creation process is completed with the double-tap action of the left hand. The deletion operation of the voxel is similar to the creation. Once you choose the voxel you want to delete with your right index finger, you can delete it with the double-tap action of your left hand.

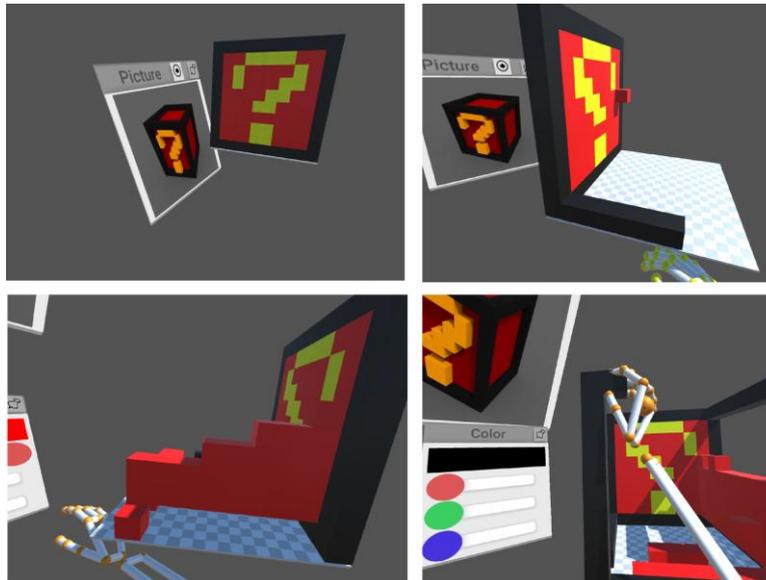## V.   AN EXAMPLE MODELING PROCESS

Fig. 3: Screenshots of Modeling Process

We have created various models to see how useful the tool and user interface. This chapter briefly describes the process by which one model was designed. First, we used left hand to call up the main menu, and called up "Pictures" sub-menu and selected one of the pictures by right hand. Then, we used "Manipulate" sub-menu to move to a position where the floor is well visible. We called up "Colors" sub-menu to change the color of the. Once the desired color is selected, we moved the index finger of right hand to the position we want to create and then we double-tapped with left hand. We repeated this operation and felt the fatigue of left hand and fixed the main menu in a well visible place. Then, in order to make another face, we selected "Manipulate" sum-menu and rotated the object under construction. When the fixed menu was overlapped, we moved the menu to another position by right hand. Occasionally, a fixed menu window became too small to be visible. Then, we could enlarge it by using both hands while viewing the menu.

IV.   CONCLUSION

In this study, we investigated the NUI-based interaction. To do this, we developed a 3D voxel-based modeling tool for immersive virtual environments using HMDs, and modeled various 3D objects using the developed tools.

As a result of modeling, most of the operations were able to be used without difficulty in the virtual space. A typical example is pinch operation. In the case of pinch, it was used for menu call and voxel movement and rotation. The double-tapping action of creating a voxel is not used very well in real life, but since it is a frequently used command, the simple operation seemed rather comfortable. In the case of the touch operation used to select the menu, since it is a frequently used operation in our real life in order to press the screen on a smartphone, it was possible to naturally perform the action. The pinch and drag action used to move the fixed menu could also be performed naturally.

On the other hand, there were also some problems that were pointed out as disadvantages. When we designed a complex object, we had to do the same operation repeatedly many times. When designing by NUI-based interactions, we can see that natural behavior is not always an advantage, although we feel very natural. It is very important that interaction behaviors should be natural but not physical fatigue. There was also the opinion that in the case of the touch operation, the user feels a sense of heterogeneity. This is caused by the fact that we cannot feel physical feedback like smartphones or touch-screens. In recent years, devices with haptic capabilities that can provide physical feedback have also begun to be released, and this problem is expected to be solved in a near future.

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