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นาย สุทัศน์ ชัยสินอนันต์กุล

ศูนย์วิทยทรัพยากร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาวิทยาศาสตร์คอมพิวเตอร์ ภาควิชาวิศวกรรมคอมพิวเตอร์

คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2552

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

WIIMOTE INTERFACE FOR CUTTING AND FOLDING  
3D DIGITAL MODEL IN ARCHITECTURAL DESIGN



Mr.Sutas Chaisinanantkul

ศูนย์วิทยุทรัพยากร  
A Thesis Submitted in Partial Fulfillment of the Requirements  
for the Degree of Master of Science Program in Computer Science

จุฬาลงกรณ์มหาวิทยาลัย  
Department of Computer Engineering  
Faculty of Engineering  
Chulalongkorn University

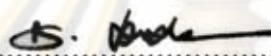
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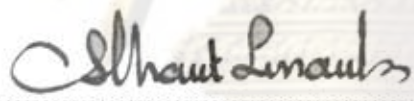
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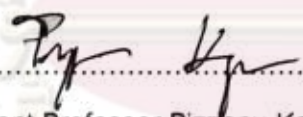
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Accepted by the Faculty of Engineering, Chulalongkorn University in Partial  
Fulfillment of the Requirements for the Master's Degree

  
..... Dean of the Faculty of Engineering  
(Associate Professor Boonsom Lerdhirunwong, Dr.Ing.)

THESIS COMMITTEE

  
..... Chairman  
(Assistant Professor Athasit Surarerks, Ph.D.)

  
..... Thesis Advisor  
(Assistant Professor Pizzanu Kanongchaiyos, Ph.D.)

  
..... External Examiner  
(Chakrit Watcharopas, Ph.D.)

คู่มือวิทยานิพนธ์  
จุฬาลงกรณ์มหาวิทยาลัย

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งานสถาปัตยกรรมนั้นเป็นวิชาที่ซับซ้อน ซึ่งเปรียบได้กับการรวมกันของระบบต่างๆ ของสิ่งมีชีวิต ในงานออกแบบสถาปัตยกรรมนั้น ผู้ออกแบบต้องจัดทำโมเดลสามมิติเพื่อสื่อถึงแนวความคิด และรูปทรงต่างๆ ในงานออกแบบที่ผู้ออกแบบได้คิดขึ้นมา แม้ว่าในปัจจุบันจะมีโปรแกรมสามมิติ เพื่อช่วยในการออกแบบต่างๆ มากมาย แต่อุปกรณ์รับเข้ายังคงเป็นเมาส์ และ แผงแป้นอักขระซึ่ง มีข้อจำกัดหลายอย่าง อีกทั้งยังใช้งานลำบาก เพราะรับข้อมูลได้แค่สององศาอิสระ ในการทำงาน จึงต้องมีการเลือกเมนูเพิ่มเติมเพื่อที่จะจัดการวัตถุในระบบสามมิติ การใช้งานที่ลำบาก และใช้ เวลาในการขึ้นรูปสามมิติในดิจิทัล จึงทำให้ผู้ออกแบบมักจะร่างแบบด้วยกระดาษ หรือตัดโมเดล จากกระดาษ เพื่อศึกษาแนวความคิดในการออกแบบ เมื่อได้แบบที่ต้องการแล้วจึงค่อยไปขึ้น โมเดลในดิจิทัลอีกที ขั้นตอนดังกล่าวเป็นการซ้ำซ้อน และเสียเวลาในการออกแบบ งานวิจัยนี้จึง พยายามแก้ปัญหาดังกล่าวด้วยการใช้อุปกรณ์รับเข้าที่เป็นสามมิติที่ใช้ในการควบคุมเกมของนิน เทนโด ซึ่งก็คือ วีโมต อุปกรณ์นี้สามารถส่งข้อมูลได้ถึงหกองศาอิสระ และง่ายในการควบคุม ผู้ใช้ เพียงแค่เลื่อน หรือหมุนวีโมตในการควบคุมรูปทรงสามมิติในระบบนี้ เหมือนกับจับวัตถุเลื่อนหรือ หมุนในทางกายภาพ ส่วนต่อประสานที่ใช้อุปกรณ์รับเข้าสามมิติในงานวิจัยนี้คาดว่าจะช่วยให้ ผู้ออกแบบสามารถขึ้นโมเดลสามมิติในดิจิทัลโดยการตัด และหมุนวัตถุได้ง่ายขึ้น และรวดเร็วขึ้น

ศูนย์วิทยทรัพยากร

จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา วิศวกรรมคอมพิวเตอร์

ลายมือชื่อนิสิต

สุทัศน์ ชัยสินอนันต์กุล

สาขาวิชา วิทยาศาสตร์คอมพิวเตอร์

ลายมือชื่ออาจารย์ที่ปรึกษาวิทยานิพนธ์หลัก

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Architecture is a complex subject which can be seen as a synthetic organism. In order to create architecture, designer needs to visualize the design by using 3D model. Although there are many 3D programs at the present, the input interface is still mouse and keyboard which limit designer to work and sit in front of the screen. In addition, it is not intuitive to manipulate 3D object by 2D input interface. As the input device receives only 2 degrees of freedom, users require additional steps to operate their task. This might be the causes which make 3D model in digital difficult and take a lot of time. Therefore the design is frequently done by sketching in a paper or making a physical model. Then designers transform it into 3D digital model. This research tries to solve this problem by proposing intuitive interface which employs Wiimote to control and modify 3D object. The input device is able to send 6 DOF data so users easily manipulate 3D object only by moving or rotating input device. In conclusion, this report supposes that this interface will provide easier and faster method for designing in the conceptual stage of design by rotating and cutting 3D object.

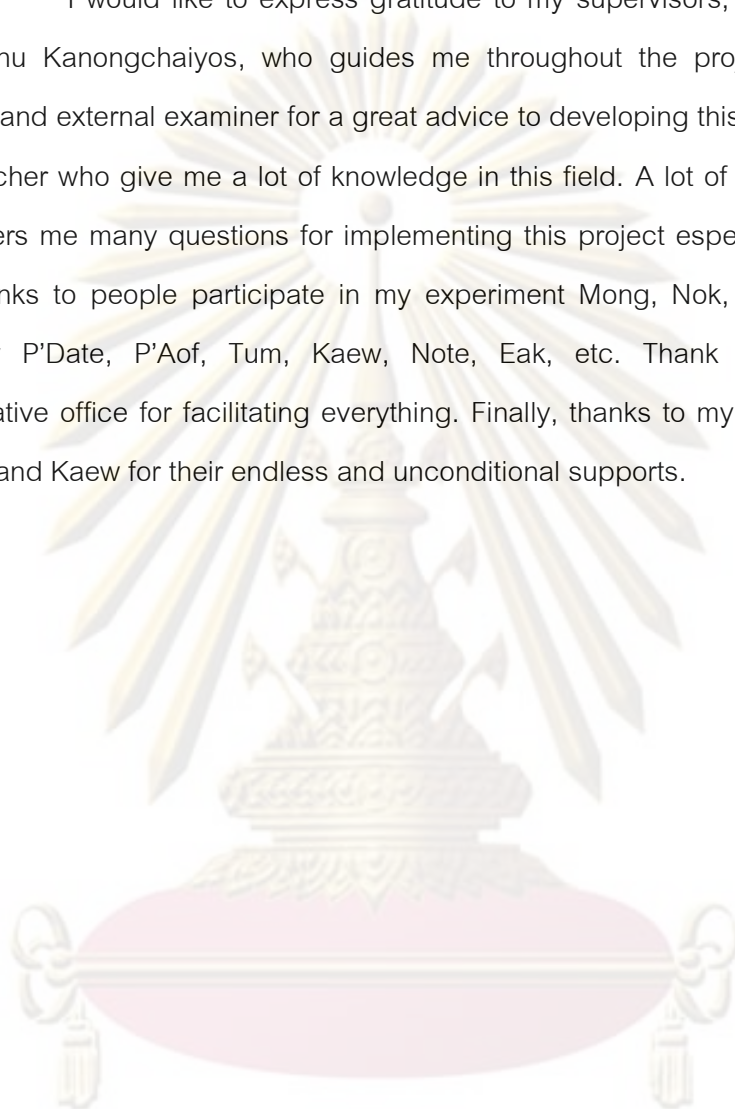
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Advisor's Signature

*Sutas Chaisinanantkul.*  
*Pizzanu Kanongchaiyos.*

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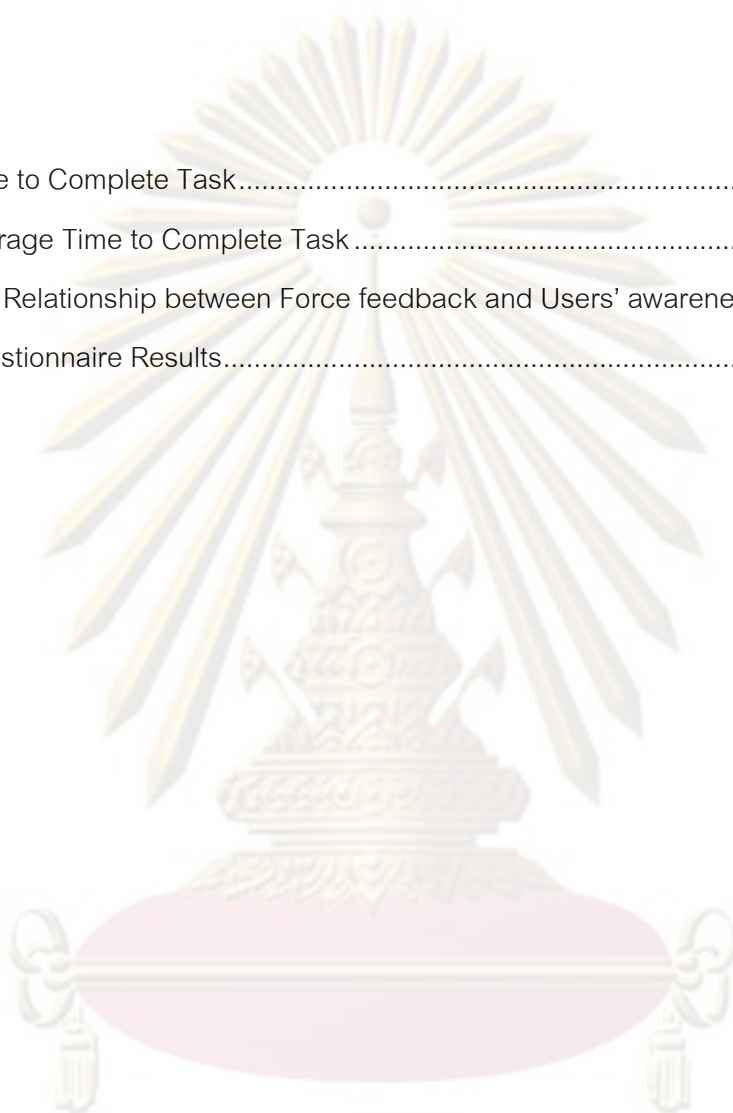
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## Chapter I

### Introduction

#### 1.1 Background and Statement of Problems

Most 3D application provide only mouse and keyboard interface for creating and manipulating three dimensions (3D) model in digital. This interface is difficult for user to use especially to create complex 3D form. Users require additional steps to do to compensate the missing DOF (degrees of freedom) of input data such as if they want to rotate 3D object in x and y axis, they have to choose icon for rotate and select the axis between x and y then move the mouse. These additional steps interrupt the flow of task while designers are working. Therefore users are interrupted by these additional steps and take a time longer than it should be to finish their task. As the result of this interface, most designers or artists refuse to use computer to be a design tool. They only use 3D digital to visualize and present their work. They prefer using pen and paper interface to sketch or 3d paper physical model then, convert their model to be digital. The poor 3D model interface using mouse and keyboard are not only making design task more difficult. Furthermore this interface keeps designers thinking on how they modify 3D digital object. In contrast, this project employs another approach of 3D input interface to create and to adjust 3D Model that ease designer to use, focus their thinking to create their work rather than thinking on how to build 3D form in digital. In addition, simple and inexpensive equipments will be used in this project, for example, USB Bluetooth adapter, Wiimote and its sensor bar. Users can easily find it in computer store.

#### 1.2 Objectives

The objective of this project is to create a 3D tool which supports 3D input device Wiimote. This tool will provide some primitive shapes for users to create 3D model. Users should be able to modify it by rotating, scaling and cutting 3D object in real time. Wiimote does not provide key to input value like a keyboard and it is controlled by movement. Thus we will not address in accuracy issue in this system. In addition, this tool should be easy to use and inexpensive. As a result of using this interface, users

should perform their tasks better in term of time. If we can reduce time to complete task and user satisfies to use our tool, we should reduce the process of design by encourage users to use 3D digital tool in preliminary design.

### 1.3 Project Scope

1. Using Wiimote connected to PC to be an input device to control 3D object
2. The movement of Wiimote can be used to create straight line and project it into slice plane to separate 3D primitive object into two pieces
3. Interface provides the ability to cut and fold or rotate 3D objects by using the movement and the orientation of Wiimote
4. During the process, user should not be too far from the USB Bluetooth adapter
5. Comparing this system with normal 3D software using mouse and keyboard
6. Comparing this system with force feedback and non force feedback
7. Observing and Evaluating the system by giving a task for users to perform in this system

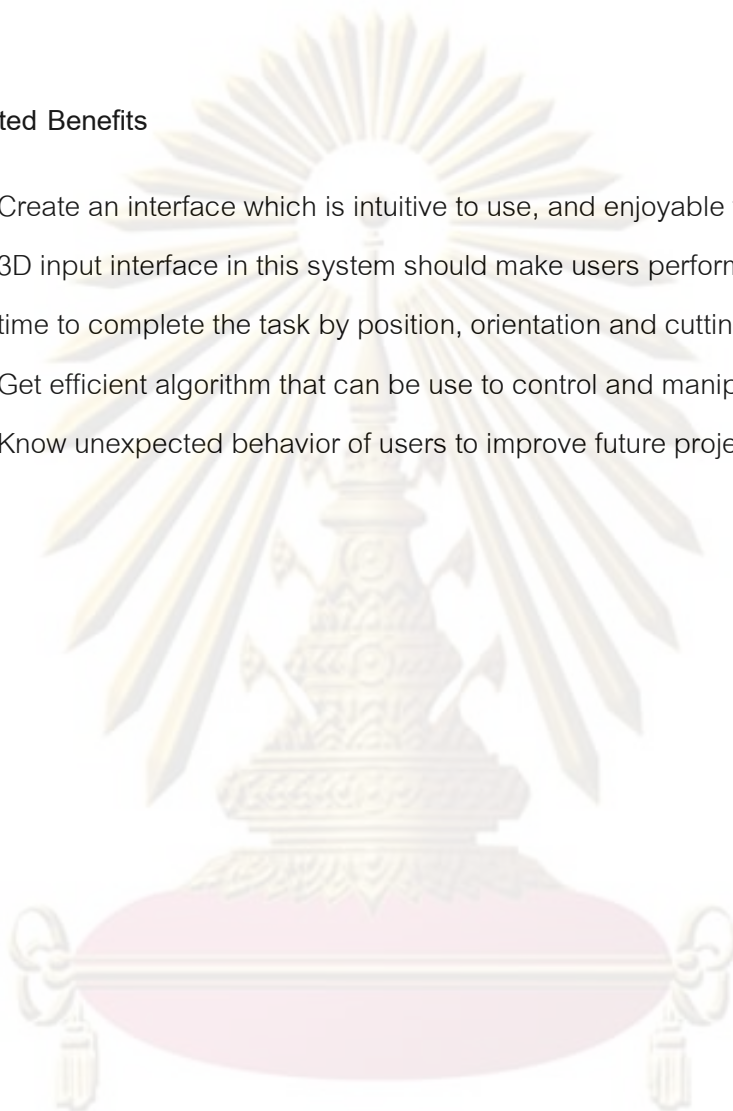
### 1.4 Research Procedures

1. Study related theories in human computer interaction, user interface and tangible Interface
2. Study existing related research
3. Study the method to connect Wiimote to computer
4. Study the library and language to use in this report
5. Design an interface and operations
6. Design the algorithm to make control device to be able to properly adjust the position and orientation of 3D digital model
7. Design the algorithm to cut or segment 3D model by using movement of control device
8. Analyze the strength and weakness of this interface while users perform their task

9. Study the behavior of users who use the system of this research
10. Evaluate and propose future development

#### 1.5 Expected Benefits

1. Create an interface which is intuitive to use, and enjoyable to use
2. 3D input interface in this system should make users perform better in term of time to complete the task by position, orientation and cutting object
3. Get efficient algorithm that can be use to control and manipulate 3D object
4. Know unexpected behavior of users to improve future project



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## Chapter II

### Related Theories and Literature Review

#### 2.1 Related Theories

##### 2.1.1 Human Computer Interaction

The term of human-computer interaction (HCI) was broader than just designing an interface since 1980s. It now covers all aspects which relate to the interaction between human and computer. As Hewett [1] states that “Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.” The intimate relation of HCI and design is obviously as Computer Aid Design has employed HCI. At the early stage of drawing system, sketch pad which was Ivan Sutherland PhD thesis in 1963 supported the manipulate object using light pen [2]. At present, much of current technology is based on his system. Along the history of development, the interface becomes more natural to use than the past. From light pen to mouse, then stylus of early 1990s, and now many interface employ gesture recognition, speech recognition, tangible interface, and virtual reality technology. Many researches utilize these approaches to enhance CAD more intuitive and effective for designer to use because designers should perform fluently to explore their thinking in conceptual design. Input hardware is one of technology which is significant to this change. In this section, we will review some of input hardware technology which is used to be interface in many systems.

##### 2.1.2 Input Device

Normally, devices which use to communicate with computer are called input device. The goal of selecting input device is to support user to work safely, effectively, efficiently and enjoyable to use. In order to, accomplish these goals. The criteria to choose input device should following these aspects. The first issue is to match physiological and psychological characteristics of users. The second issue is appropriate with the task that users perform. For example, drawing system should use

input device that support free movement to create form. In contrast, to select menu or option, the input device should be discrete movement device. The third issue is that the input device is expected to suitable for intended work and environment. The condition to accomplish task often differs from each other depending on the environment and characteristic of task. For example, if system employs speech input device to control system, the environment should be quiet or have a little noise. Input devices can be divided by the way users interact with them. Input devices can be classified into two categories [3]. The first is devices which are used for text entry such as keyboard or using speech recognition. The second is devices that use to point and select object in the screen such as mice, joystick and touch screen.

### 2.1.3 Interaction Techniques

Input devices can be divided by its dimension of input [4]. First is one dimension input such as keyboard. The entry of this input usually is text. Second is 2D pointing device. These devices use to control the location of cursor on the screen by synchronize with the location of moving hand. One of these devices is mouse which is indirect input device. It controls cursor by capturing movement on 2D planar. This device can lift up and change position which is an advantage when working space is limited. It is however, not intuitive enough for novice users. Another 2D pointing device is joystick. It uses rotation of two axes to control the cursor. Although users easily control cursor by this method, it is difficult to use it for drawing task. This is the same as track ball which users control position by turning knob. On the other hand, there are also 3D input devices. Normally, these devices evolve from changing 2 degrees of freedom (DOF) to 6 DOF. The following examples are some of 3D input devices.

The 6D mouse allows users to control by sensing six parameters which are position in x, y, z coordinate including orientation in pitch, roll, and yaw (Figure 1).





Figure1 Six DOF mouse



Figure 2 3dconnexion® SpaceMouse

Figure 1 Source: Inition. Ascension 6D Mouse

Figure 2 Source: Diniz N., An Approach on 3D Digital Design Free Hand Form Generation. University College London, 2003.

The SpaceMouse allows users to control and interact with 3D graphic objects. By slightly pressing onto the cap or twisting, users can change the position and orientation of 3D objects in the scene (Figure 2).



Figure 3 Flock of Birds® and Nest of Birds® (wireless), Ascension Technology Corporation

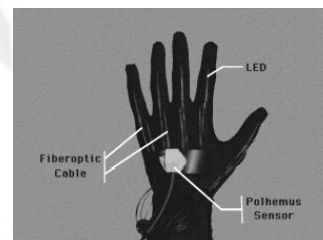


Figure 4 Data Glove

Figure 3 Source: Diniz N., An Approach on 3D Digital Design Free Hand Form Generation. University College London, 2003.

Figure 4 Source: Thalmann D., Introduction to Virtual Environments. Computer Graphics Lab. Swiss Federal Institute of Technology.

The Flock of Birds® and the Nest of Birds® from Ascension Technology Corporation create direct translation of position and orientation of the input device status in 3D space. These devices employ magnetic sensor to sensing data so it is sensitive to metal. The advantage of this system is the precise in position and orientation.

Nevertheless, its weakness is the cost of this system which is more than 200,000 baht for two sensors flock of bird configuration (Figure 3).

Data glove is a glove worn technology which user can grasp and move to interact with virtual objects (Figure 4). Sensors are connected via cables to interface board near the wrist which in turn connect to the computer. By this method, hand and finger position can be sensed to the system. Usually, this device is used collaborate with other devices such as head-mounted displays (HMD) to view object in 3D. The strength of data glove is its precise and intuitive control by using hand to be an input. However, its weakness is its cost and it is not convenient for users to wear for a long time. [5]

## 2.2 Related Work

From the problem of using mouse to draw 3D model, there are many projects try to solve this problem. These related projects can be categorized into two groups. The first group is in section 3.1 and 3.2. This group employed virtual reality and sensor to create 3D model. The other group is in section 3.3 and 3.4. This group based on image processing and computer vision.

### 2.2.1 Surface Drawing: Creating Organic 3D Shapes with the Hand and Tangible Tools (2001)

This project uses hand movement to create organic 3D shape in semi-immersive virtual environment [6]. Users wear head mounted display to see 3d virtual object that users create, augmented in the real world. There are many tools for creating and interacting with 3D model. The first is the glove, user wears glove and presses the button between thumb and index finger to start a stroke. The second is tongs. This tool provides ability to move, scale and rotate 3D model. The third is eraser which is made from silicone. Users can activate this tool by squeezing it then it will remove 3d object as in Figure 7. The last one is magnet drawing which is used for modify object.



Figure 5 Glove  
to draw surface



Figure 6 Tongs to  
move and scale 3d  
model



Figure 7 Eraser to  
remove 3d objects



Figure 8 Magnet  
Drawing to modify  
3d model

Figure 5-8 Source: Schkolne S., Pruetim., P. S. Surface drawing: Creating organic 3d shapes with the hand and tangible tools. In Proc. of CHI, 2001.

### 2.2.2 Tangible + Virtual = A Flexible 3D Interface for Spatial Construction Applied to DNA

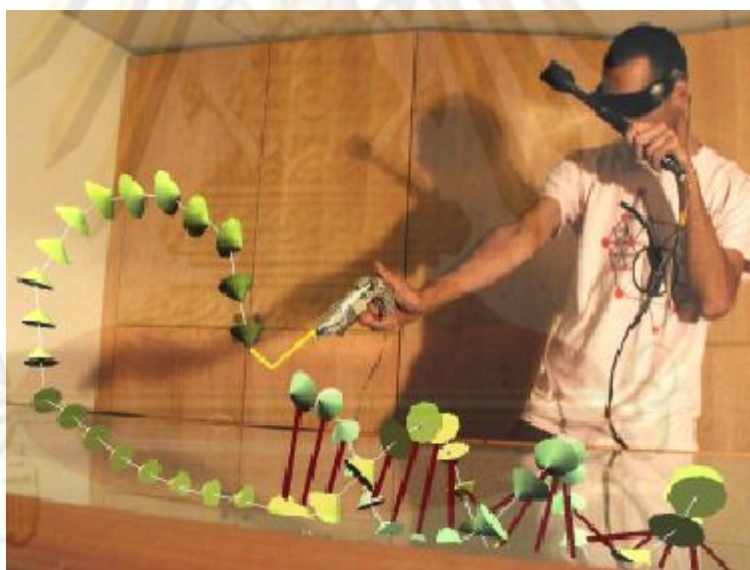


Figure 9 A Flexible 3D Interface for Spatial Construction Applied to DNA

Figure 9 Source: Schkolne S., Ishii H. Schroeder P. Tangible+ virtual = a flexible 3d interface for spatial construction applied to DNA. California Institute of Technology, 2002.

This project is similar to the first project but it is designed for helping research in molecular biology to construct DNA [7]. There are many physical tools that are used in this project. First, is a ray gun which is used for picking point in space. It is modified

from toy but, it is inserted motion tracker and sensor button to activate this tool. As construction DNA needs to be precise selection within a dense volume such as user wants to draw bond between base DNA. The purpose of this tool can compare with gluing object. Second, is a grip tool which is for controlling 3D location. In addition, users are able to create and cut DNA by this tool. The last one is tongs which is used for manipulating object. DNA that is created can be local or global transformed and scaled by this tool.

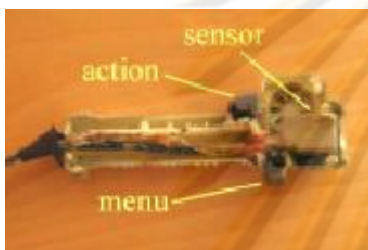


Figure 10 Grip tool



Figure 11 Tongs



Figure 12 Ray gun

Figure 10-12 Source: Schkolne S., Ishii H. Schroeder P. Tangible+ virtual = a flexible 3d interface for spatial construction applied to DNA. California Institute of Technology, 2002.

#### Advantages of the first group

- Users immerse with 3D model which they create
- Users spend a little time to learn how to use these system
- Techniques for creating 3D model in these system are easily and natural to use
- Users are enjoyable to use these system

#### Disadvantages of the first group

- The equipments which are used in this group are not available in ordinary store and they are very expensive.
- Cables of input devices may obstruct users' task.
- It is not convenient for users to wear HMD (Head Mounted Display) and Data Glove for a long time.

There are many advantages of these interfaces because all of these interfaces employ tangible tool and hand to be an input device. These decrease a lot of learning period to create 3D model for user comparing with keyboard and mouse input interface. Furthermore, user can enjoy intuitively creating and manipulating 3D model. However, all of these tools have wire which is obstacle for users to control and manipulate 3D models for example it is difficult to rotate 3D object because of the wire. Moreover, these two projects used virtual reality tool such as glove which is expensive and difficult to find.

### 2.2.3 An Approach to 3D Digital Design: Free Hand Form Generation

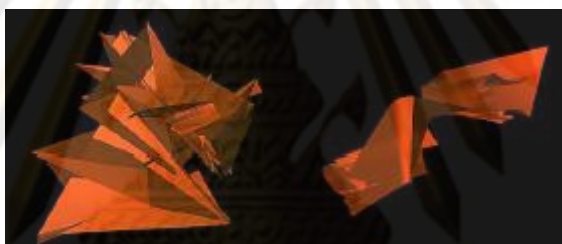


Figure 13 An Approach to 3D Digital Design Free Hand Form Generation

Figure 13 Source: Diniz N., Branco C. An Approach to 3D Digital Design Free Hand Form Generation. Proceedings of the Eighth International Conference on Information Visualisation, 2004.

This project proposes free hand drawing interface to draw 3D surface [8]. It uses only two web cameras and two light's (LED's). Two LED's are attached to the finger of user to be interface input. User moves their hands to draw 3D surface. Two web cameras are used to track the position of LED's. One web camera is for tracking coordinate in x and y axis and another one is used for finding position in z axis.

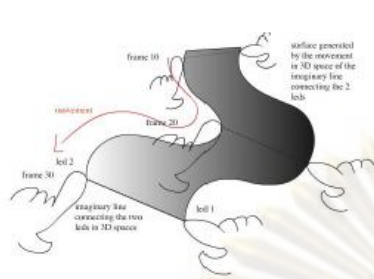


Figure 14 Movement in 3D space as a surface generator

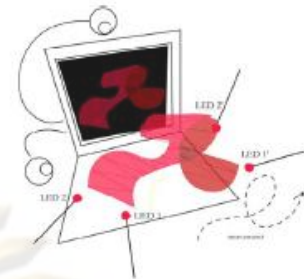


Figure 15 Diagram of the form-generation system

Figure 14-15 Source: Diniz N., Branco C. An Approach to 3D Digital Design Free Hand Form Generation. Proceedings of the Eighth International Conference on Information Visualisation, 2004.

This project solves wire problem that is obstacle to draw as user use only LED's which are attached to their fingers. Nevertheless, the constraint of this project is that users have to use both hands to draw which is difficult for some movement or form.

#### 2.2.4 Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction

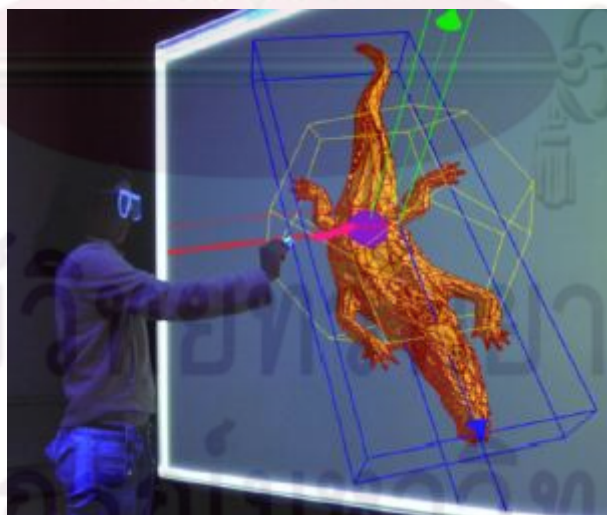


Figure 16 Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction

Figure 16 Source: Kim H., Albuquerque G., Havemann S., Fellner D.W. Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction. Computer Graphics Forum, 2005.

This research also solved the wire problem which happened in surface drawing project by employing bare hand to be an interface [9]. However, users have to mark their hand by wearing four fingertip–thimbles which are made from white paper. Stereographic is used to display 3D objects. Users wear a polarized glass which is covered by white paper for ease tracking view point. This system composes of screen, two back projectors, web camera, black light, polarize glass and white paper.

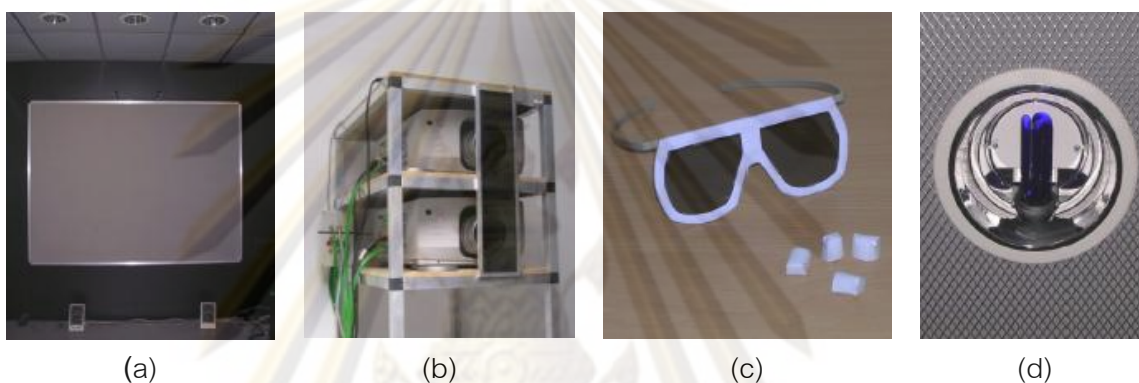


Figure 17 Tangible 3D system environment: (a) back-projection screen, (b) two projectors for passive stereo, (c) user interfaces – white paper-rimmed polarized glasses and fingertip markers (d) a black light

Figure 17 Source: Kim H., Albuquerque G., Havemann S., Fellner D.W. Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction. Computer Graphics Forum, 2005.

Users can intuitive manipulate 3D object using their gesture. Each posture of finger is defined for each operation as in figure 18.

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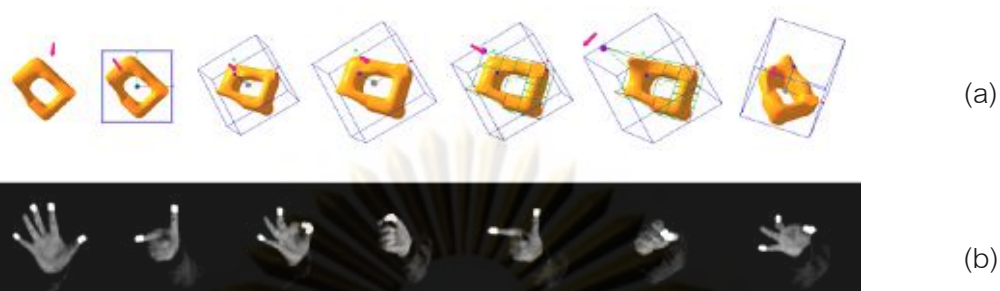


Figure 18 Hand gesture interaction : (a) object manipulation and deformation (b) the sequence of gesture interaction– pause, point(object), rotate, translate (z-direction), point(object's vertex), translate(object's vertex), and rotate

Figure 18 Source: Kim H., Albuquerque G., Havemann S., Fellner D.W. Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction. Computer Graphics Forum, 2005.

#### Advantages of the second group

- Users spend a little time to learn how to use these system
- Techniques for creating 3D model in these system are easily and natural to use
- Users are enjoyable to use these system
- Equipments and tools which are used in these project are easy to find and inexpensive.
- Input device of these system are wireless

#### Disadvantages of the second group

- Unlike the first group, it is not immersive system.
- The environment have to be controlled because the limitation of tracking algorithm such as ambient light and distance from cameras.
- Only one user can interact with the system because the limitation of tracking algorithm.

In brief, All of these project try to create intuitive interface for 3D modeling. In Surface Drawing and A Flexible 3D Interface for Spatial Construction Applied to DNA



have wire problem so users may not convenient to move or rotate around to interact with 3D objects. In Freehand Form Generation and Tangible 3D solve wire problem. Moreover they used ordinary tools which are not expensive and easily to find in computer store.



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## Chapter III

### Methodology

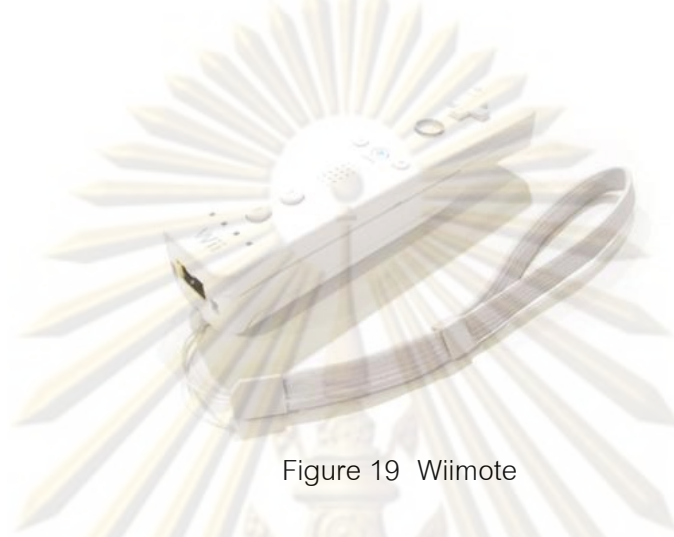


Figure 19 Wiimote

The concept of this research will test the idea about using 3D input to roughly create and modify 3D model. Therefore we have to build 3D system which receives input from Wiimote. This input device should be able to control and modify 3D object by translating, rotating, scaling and cutting.

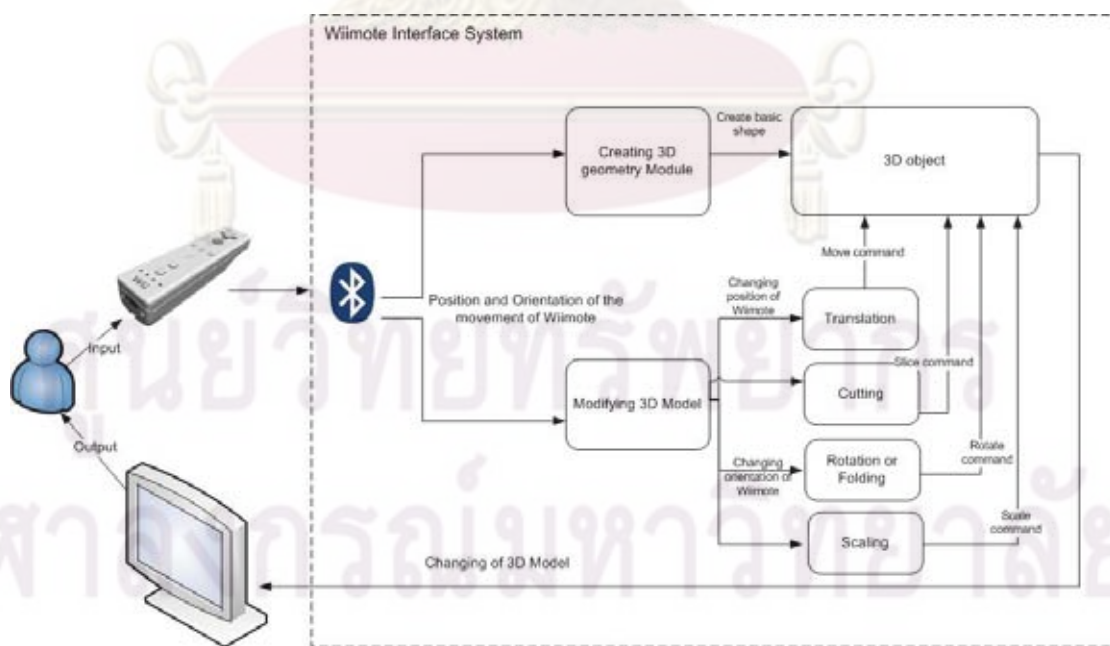


Figure 20 System Overview to manipulate Object

In order to implement this system, we require two significant parts which are hardware and software. The software part is closely related to the interface of the system as it will manage the input to control 3D object. After all parts are completed, we will evaluate our system comparing with the general 3D software which is manipulated by mouse and keyboard.

### 3.1 System Hardware

#### 3.1.1 Bluetooth Device

WiiMote communicates with computer via a Bluetooth device. However the problem is some of Bluetooth device and Bluetooth stack does not support to send and receive data from WiiMote to computer. Therefore to connect WiiMote, system should have proper Bluetooth adapter and Bluetooth stack. In this project, Toshiba Bluetooth adapter and BlueSoleil version 5.0.5.178 software will be used to communicate with WiiMote (Figure 3.3). [10]



Figure 21 Wiimote Bluetooth connection

#### 3.1.2 Wireless Sensor Bar

WiiMote is able to use as a pointing device. However it requires sensor bar. The IR camera in front of wiimote which is CMOS monochrome camera will detect signal from IR LEDs. Then software system interprets that to be a position on screen. This wireless sensor bar consists of two AA batteries, two 1.5 k $\Omega$  resistors, two 470 k $\Omega$  resistors, 220  $\mu$ f capacitor, 470  $\mu$ f capacitor, three transistors no. 2SC1815, 8 IR LEDs, one red LED and one 7 mH inductor (Figure 3.5). [11]

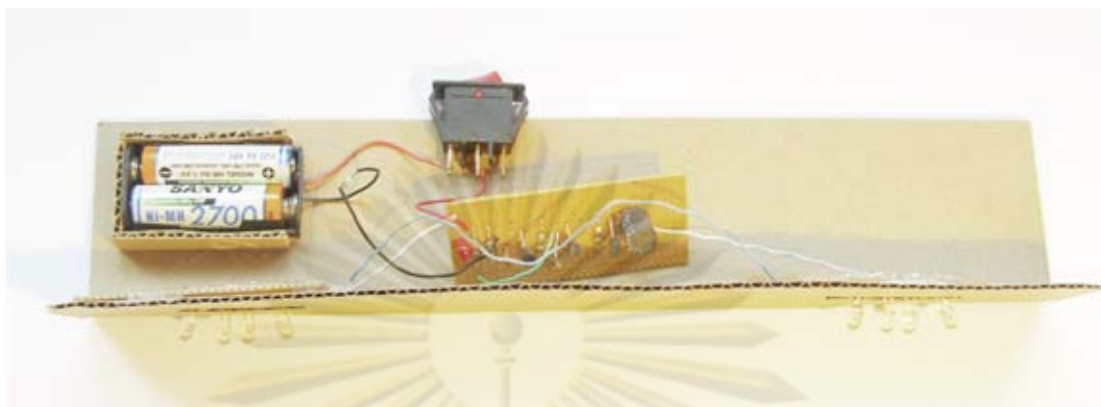


Figure 22 Wireless Sensor Bar

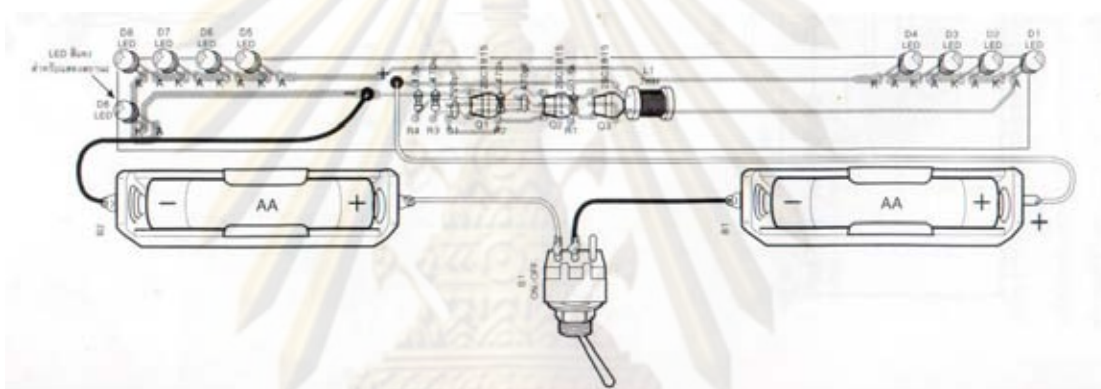


Figure 23 Wireless Sensor Bar Circuit [11]

Figure 23 Source: Sosuwan K., Wireless Sensor Bar for Nintendo Wii Console. Hobby Electronics, 2007

### 3.1.3 Wiimote

Wiimote is a game controller for Nintendo's Wii console. In September 2007, a Nintendo Wii game console has sold more than 13 million consoles [10]. This amount is vast over the number of Tablet PC sales. Traditionally, the motion of Wiimote is sensed by 3D axis linear accelerometer (ADXL330). Moreover IR sensor is added to Wiimote because motion sensor is not accurate enough to control onscreen cursor. IR sensor which is in front of Wiimote will track the position of two beacons. These two beacons are in the Sensor Bar. Tracking of these two beacons, system can make more accurate of pointing information. Wiimote also have 12 buttons to send data, when they are pressed or released, to the host via HID input report. The ability to senses 6DOF data

and its cost is inexpensive. Therefore, in this project will employ Wiimote as an input device to modeling 3D object.

### 3.2 System Software

Software in this system is implemented by using Adobe Flash which is based on actionscript 3.0. This system comprises of two main parts. First is 3D engine in Adobe Flash. It is called Papervision3D [12][13]. The second part is WiiFlash API [14]. It is written in dot net to handle wiimote communication with Flash. After combining these two parts, this system should be able to receive data from Wiimote via WiiFlash API. Then it uses this data to control 3d model in Papervision3D. In the following section, we will explain solution which is employed to map the movement of Wiimote to model in our system.

#### 3.2.1 Cursor Position

In order to use Wiimote as a mouse cursor, system has to process the position of two IR LEDs via the Wiimote IR camera and converts these data to be a screen point coordinate. Finally, system will find the average position between two points to employ it as a position of cursor.

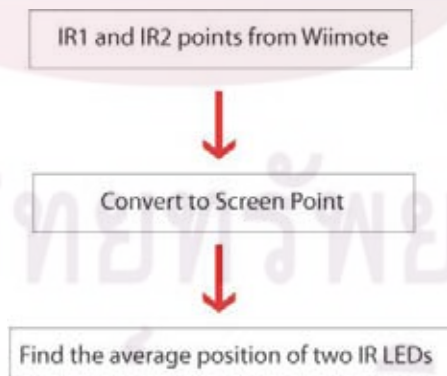


Figure 24 Process of Transforming IR LEDs Data to Cursor Position

Wiimote receives two beacons from LEDs sensor bar. The return value of these two beacons from WiiFlash will be range from 0 to 1. If the IR point is on the top left, its

coordinate is (1, 0). Thus the coordinate for bottom right is (0, 1). Coordinate of Adobe Flash in top left is (0,0) and bottom right is (1,1). Hence, the data receives from Wiimote is converted as following formula.

x screen coordinate = screen width-( x position from Wiimote \* screen width)

y screen coordinate = ( y position from Wiimote \* screen height)

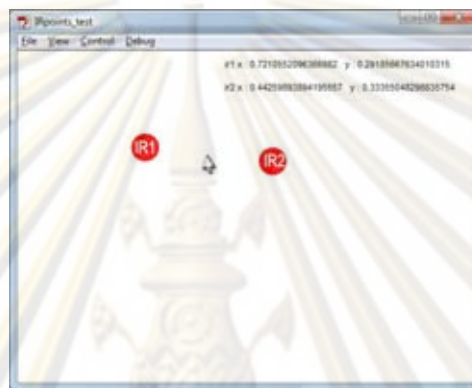


Figure 25 Cursor Position between IR LEDs

While user moves Wiimote, there is a possibility that one IR LED might be out of the IR camera view. This following algorithm is employed to calculate cursor position even though only one LED is detected. [15]

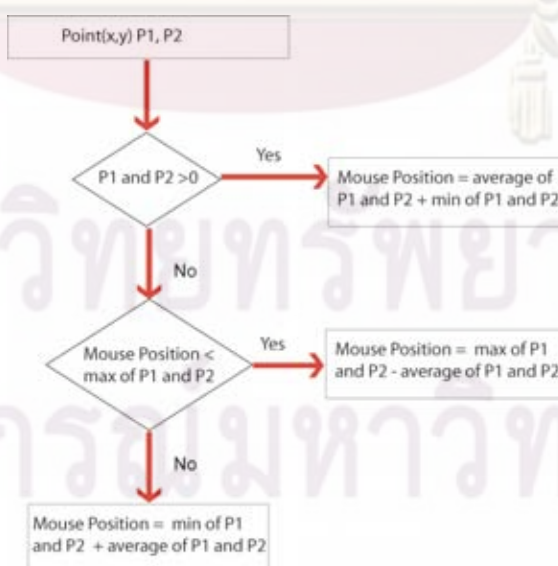


Figure 26 Algorithms to Stably Detect Mouse Cursor

### 3.2.2 Picking Object

For selecting object, system has to convert the position of mouse cursor which is screen coordinate to coordinate in 3D space. The screen coordinate origin is on top left however the 3D coordinate is on the middle of screen. Thus the following formula is used to convert the screen coordinate to 3D coordinate in Papervision3D.

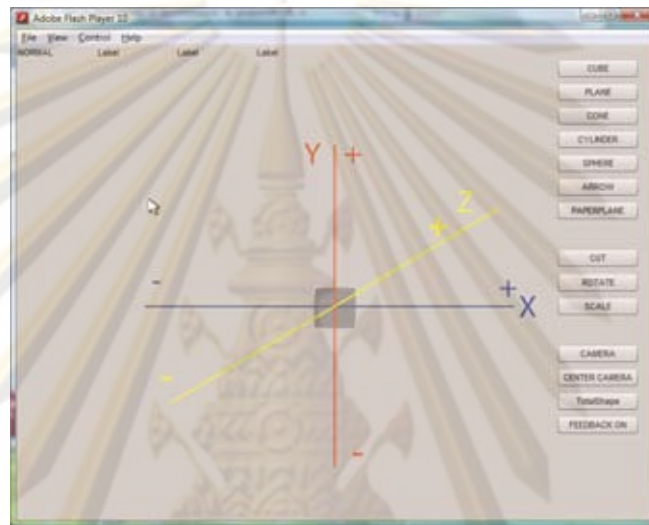


Figure 27 Coordinate in Papervision3D

X position in 3D space = position of mouse cursor in x - (screen width\*0.5)

Y position in 3D space = position of mouse cursor in y - (screen height\*0.5)

After that we use this point to check that it intersects with any object in scene. If this point is in any object, this object will be selected.

### 3.2.2 Translate Object in XY axis

When user clicks on the screen, the position of cursor will be used to create a ray by shooting it from camera. The camera position will be added to get the world position of our ray. While user is moving the mouse cursor, system will calculate the intersection of plane in xy axis and our ray to and translate object to that position. [16]

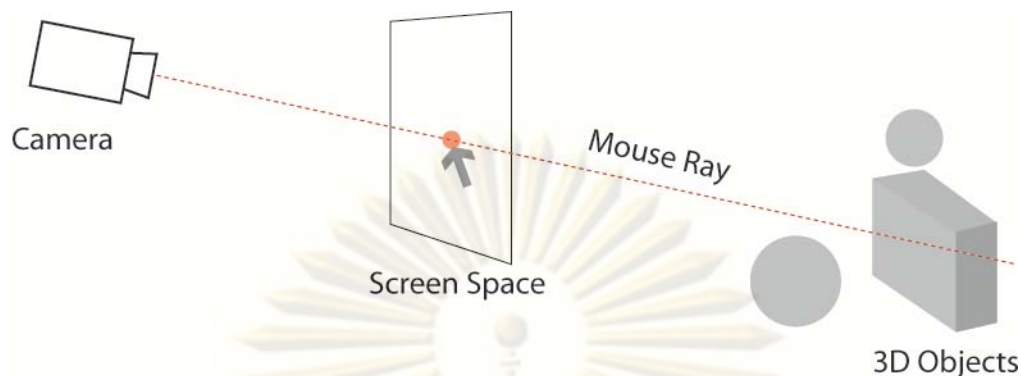


Figure 28 Creating Mouse Ray to Translate Object

### 3.2.3 Translate Object in Z axis

Down button is employed to translate 3D object in z axis. When user press the down button, system will check that both LEDs are detected to record the distance between two LEDs in x axis. While user are moving Wiimote, the new distance is recorded and is used to compare with the old one. The different between these two values will be used to move object in z axis.

### 3.2.4 Rotate Object

3D object will be rotated according to the orientation of Wiimote. WiiFlash API return roll, pitch yaw value of Wiimote in radian. On the other hand, rotation 3D object in Papervision3D is degree. Hence, system converts radian to degree before using it to rotate object. Data, which receives from Wiimote, is too sensitive. User's hand cannot stay still all the time. There is always a little movement. If we employ data from Wiimote directly to rotate, the motion of object will not be smooth. Therefore this system must filter out data so the movement of object will not jiggle. This following line is the method which is used to smooth data. [15]

Rotation degree = ((wiimote orientation\*(180 /  $\pi$ )\*3) - object orientation)/Easing



### 3.2.5 Scale Object

3D object is scaled depending on the distance between user clicks and drags the wiimote. When user clicks, system will record the point of mouse cursor. Then system employs this point data to compare with current mouse cursor while user is moving Wiimote. The distance between these two points will calculate to scale object. For example, if user clicks and drags Wiimote in x axis, this distance in x axis will be used to scale 3D object in x axis. For scaling object in z axis, user has to push the down button of Wiimote which will be described in interface section.

### 3.2.6 Cut Object

The sequence to do a cut operation starts from user selects object. Later user must change to cut mode. Then user defines cutting plane by click to define the first point. While user is dragging Wiimote, last point is defined by position of cursor. After that, system creates a cutting plane from these two points projecting these along z axis.

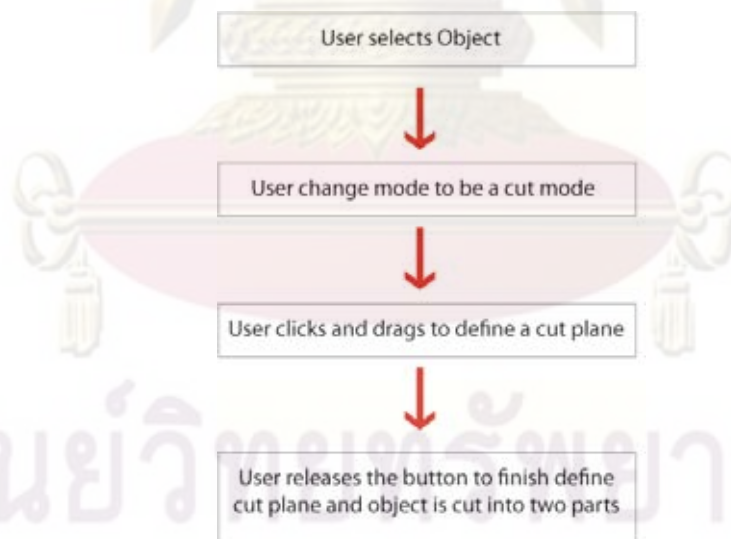


Figure 29 Cut Operation Process

Finally, our system calculates the intersection of plane and object. The intersection points are used to separate object into two pieces. For cutting object in this system, we employed MeshUtil class in Papervision3D engine. Object's vertices do not update

therefore we have to transform the plane back in order to cut the object. MeshUtil class returns an array which contains mesh objects. This system checks this array to decide that the state of cutting operation. Then it dispatches event to notify the state. The algorithm to cut object is described in the following diagram. [17] [18] [19]

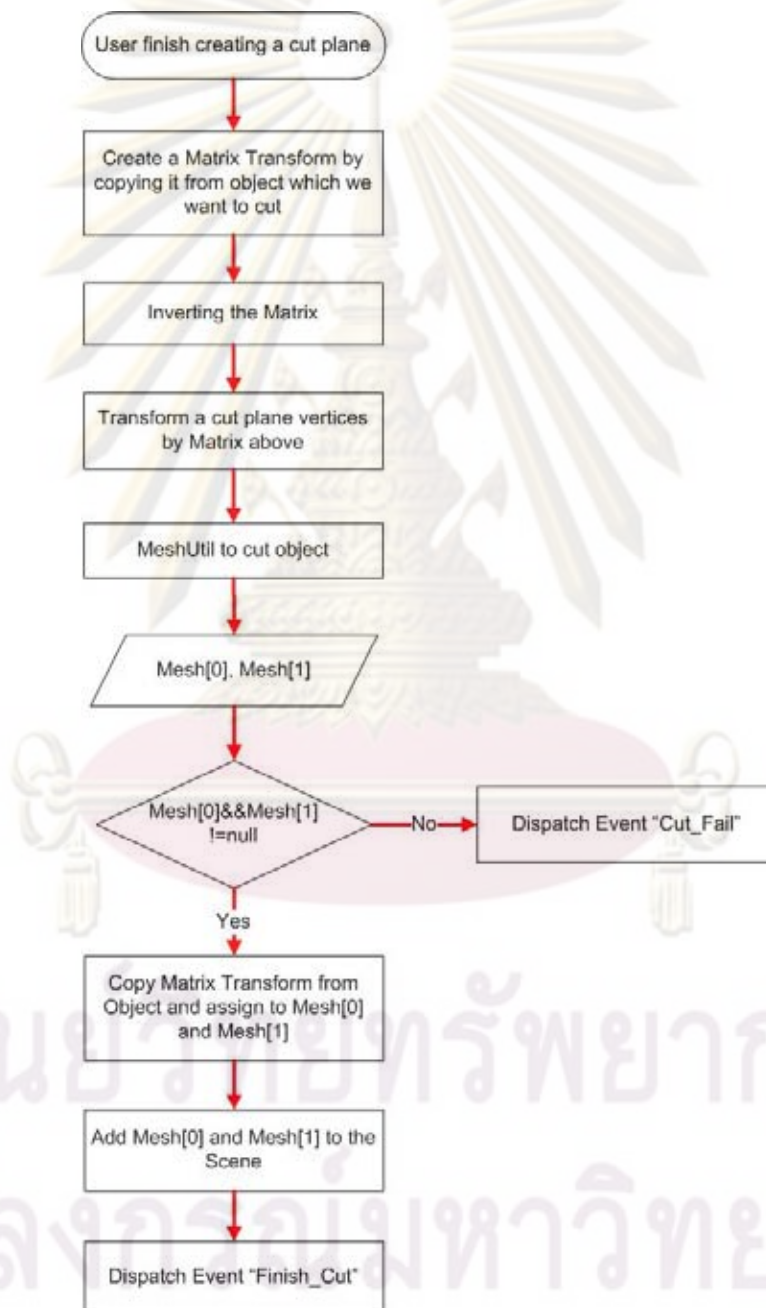


Figure 30 Algorithms for Cut Operation

### 3.3 System Interface

Interface of this system comprises of menu on the right side, cursor, two circles represented IR LED, and status of mode on top left. The right menu bar is divided into three main groups. The first group is for creating primitives object. The next one is for manipulating object which is to cut, to rotate and to scale. The last group is for manipulate camera and force feedback.

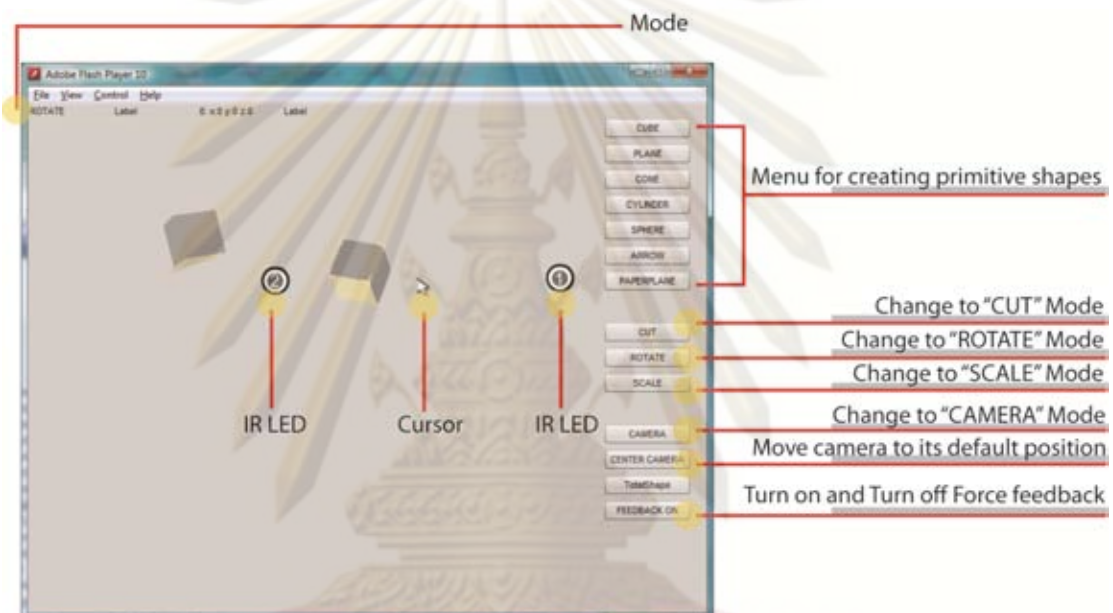


Figure 31 Algorithms for Cut Operation

There are five modes to operate in this system. Normally, user presses HOME button and LEFT button on Wiimote to change into different mode. In normal mode, user is able to translate 3D object. The A button is similar to left mouse click. User pushes A button to select any objects or menu. If object is selected and user drags Wiimote, object will be translated in xy axis. On the other hand, user pushes down button and moves Wiimote far away or close to sensor bar to translate object in z axis. In addition, PLUS button and MINUS button are for copying object and deleting object.

For rotating mode, user pushes B button to rotate in all axis. Object is able to rotate only one axis by pushing RIGHT, UP and DOWN button. RIGHT button is for rotating only x axis. User pushes RIGHT button and pitches Wiimote to rotate object

around x axis. UP button is employed to rotate only y axis. While user pushes UP button and rolls Wiimote, object is yawed according to the orientation of Wiimote. The range of yaw data which Wiimote can sense is only from 20 degrees to -20 degrees. Therefore Wiimote roll is used to compensate this limitation. For rotating only z axis, user has to push DOWN button and rolls Wiimote to rotate object.

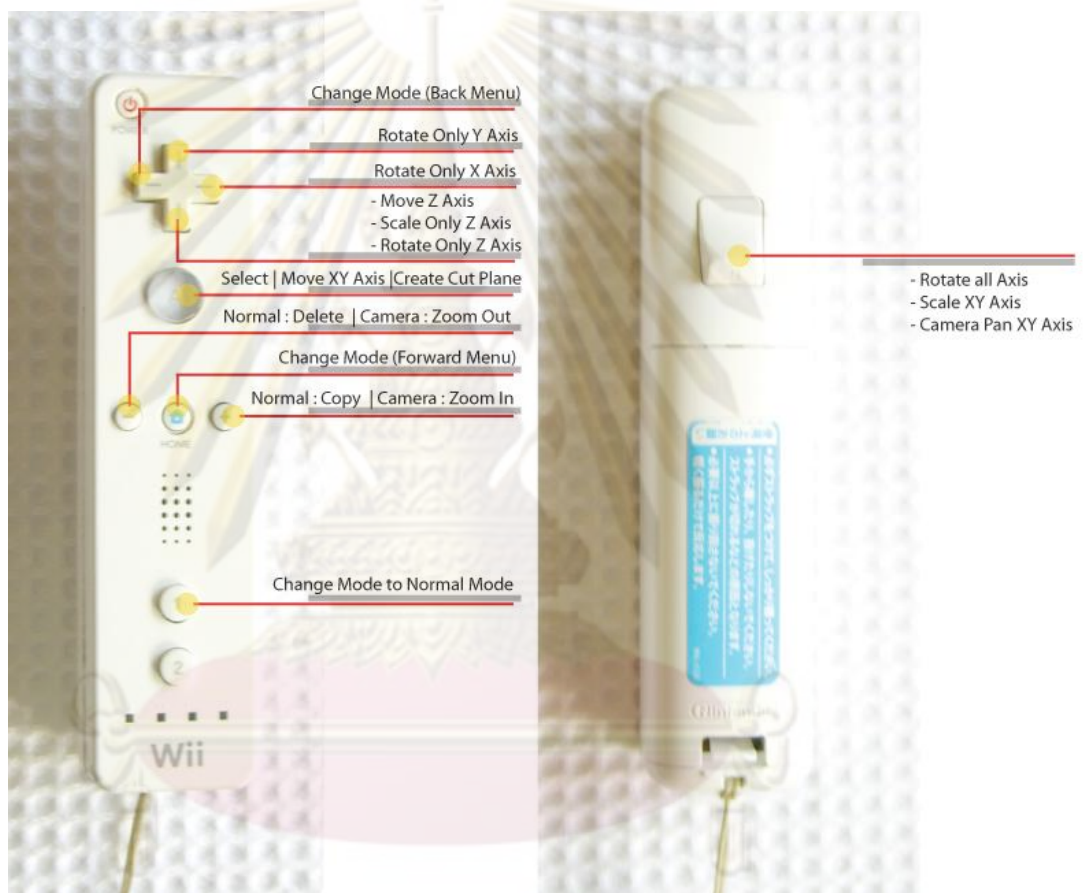


Figure 32 Algorithms for Cut Operation

User manipulates scale of object by selecting SCALE mode. While user is pressing B button and moving Wiimote, selected object will be scaled in xy axis according to the movement of Wiimote. For example if user moves cursor up in y axis, object will be increased scale in y axis. In order to scale object in z axis, user must press DOWN button and move the Wiimote in z axis to come closer or further away from sensor bar.

This system provides a method to cut object into two pieces. An object which is going to be cut has to select. Then mode must be changed to CUT mode. Next A button is pressed to define a first point of cutting line and Wiimote is dragged to define the last point as described in above section. After user finishes defining a cutting plane, A button is released and object will be cut according to the intersection of cutting plane and object.

In CAMERA mode, camera is rotated in x axis by pressing RIGHT button and pitch Wiimote. Camera rotation in y axis is the same as rotating object around y axis. User presses UP button and rolls Wiimote to orbit camera around y axis. Furthermore, user pans camera by pressing B button and move the cursor. If the cursor is moved to the left side, camera will be moved to the left. This is the same as to pan camera in right, up or down direction. Moreover, user zooms in or zooms out by pressing PLUS button and MINUS button. There is also a menu to restore camera's position and orientation back in its original position and orientation. This menu is on the right hand side below the CAMERA menu. User just presses it to return camera to its original point.

The FEEDBACK menu, at the bottom of right hand side, is for turning on and turning off force feedback of Wiimote. If it is turned on, Wiimote will rumble when user click any menu. In addition, a little vibration occurs while user selects object or copies object. Finally, wiimote will vibrate quite strong after user succeeds in cutting object.

### 3.4 Evaluation

After all parts of this system are implemented, we will evaluate this tool comparing with mouse and keyboard manipulation in a general modeling tool. Subjects in this experiment are divided into two groups. The first group is normal users who is rarely or never use 3D software. Another group is designers who frequently use 3d software to create 3D model. The experiment is set up to test our hypotheses by giving users a task to make 3D model in our system and general tool.

### 3.4.1 Hypotheses

This project addresses the performance of 3D input device and the user's satisfaction. In order to compare these two systems we used several questionnaires to evaluate users' opinion and also recorded time spending to finish the task. These followings are our hypotheses.

- The wireless 3D input device Wiimote is more efficient than mouse and keyboard in term of time to roughly model in 3D
- Users should be more satisfaction in Wiimote than mouse and keyboard
- Force feedback in Wiimote should enhance users' performance to operate task and should not interfere users while they are manipulating 3D model in this system.

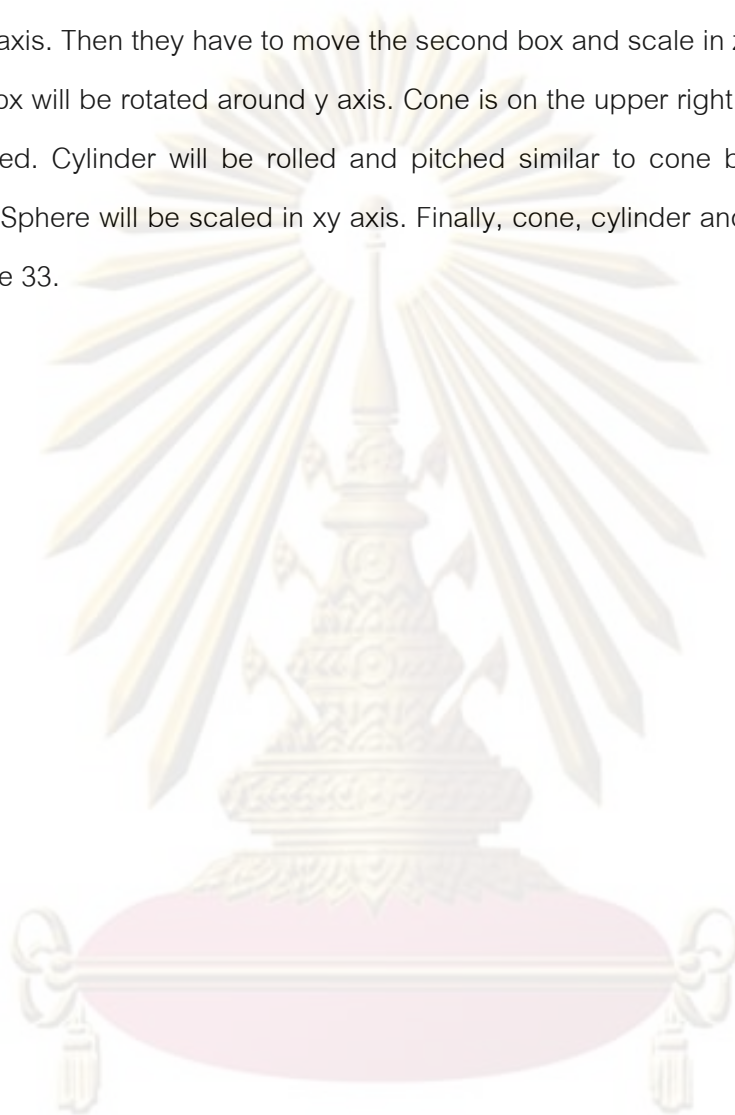
### 3.4.2 Task

In this system, there are many primitive shapes which are ready to create such as box, sphere, cone, cylinder, plane, arrow and paper plane. Furthermore, this system supports many operations which are translating, rotating, scaling and cutting object. Hence the task, we will give users to do involving these operations. Users are asked to create four different shapes. Then they have to translate, rotate, scale and cut these objects as the picture below.



Figure 33 Task for Experiment

In order to complete the task, users have to create all objects and translate to the position related to figure 33. There are two boxes in scene. Users must scale the first box in xy axis. Then they have to move the second box and scale in z axis. After that the second box will be rotated around y axis. Cone is on the upper right which will be rolled and pitched. Cylinder will be rolled and pitched similar to cone but it is in opposite direction. Sphere will be scaled in xy axis. Finally, cone, cylinder and sphere will be cut as in figure 33.



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## Chapter IV

### Data Analysis and Results

#### 4.1 Preliminary Test

After we finished building the first prototype, we tested our system with 5 users. Three of them are expert users who are in the design field and frequently use 3D system. The other two users are ordinary users who are not familiar in 3D system. The first prototype we produced is quite different from currently interface which is described in above section. DOWN button in the first prototype is for translating and scaling in Z axis. Most operations are controlled by A button (figure 34). B button is designed for going to CUT mode directly. ONE and TWO button are employed to rotate camera around x and y axis. The other buttons which are HOME, MINUS, and PLUS button are the same as current interface.

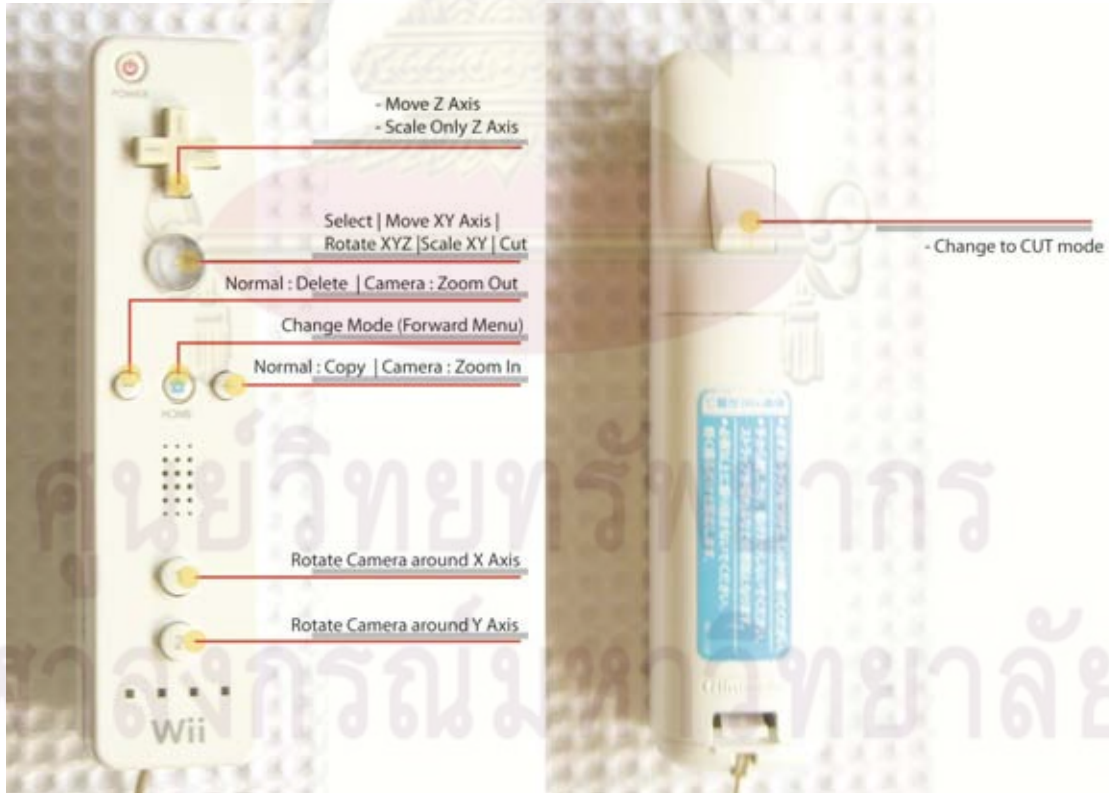


Figure 34 The First Interface



The result of testing the first prototype was collected from users via an observation and interview. All users reported unsatisfy and difficult to use this system. We found that the causes of problem might come from these following lists.

- A lot of errors occur when user selects other object in other mode which is not NORMAL mode. User presses A button to select object and object is operated immediately. For example, in ROTATE mode, user just wants to select other object. After it is selected, it is also rotated immediately according to the orientation of Wiimote. However user does not want to rotate it. This brings to the unsatisfy result. A lot of users ask for undo operation while doing this.
- Scale operation was very sensitive. User just moved Wiimote a little but the object was scaled bigger than they thought a lot. In addition, Wiimote sometimes failed to detect one LED or both LEDs. Object was scaled a lot according to this.
- User accidentally pressed B button many times so they were in CUT mode. As they did not aware this situation and they did not change the mode back to NORMAL mode. They unintentionally cut object which they did not want.
- Users awkwardly posed their hand because the object did not rotate as their want. The causes of this problem might come from two causes. The rotation all axes at once makes user difficult to control and the range of Wiimote orientation which we receive is not cover all 360 degrees.

The current system was improved by changing button to operate 3D model. We adapted A button to operate only selecting, moving and cutting object. B button is employed to rotate and scale object. Thus two problems were eliminated which were accidental errors from rotating and scaling object and accidental pressing B button. For the problem of scaling object, we decreased the speed of scaling object. Moreover we also limited value of input for scaling within some range. Hence, its value is still acceptable, although Wiimote fails to detect LEDs. The problems in rotation object were corrected by expand the range of input to cover all 360 degrees. Furthermore, the UP,

RIGHT, DOWN buttons are added to rotate only specific axis. The result is current interface.

#### 4.2 Data Analysis and Results

	Group I (Normal Users)					Group II (Designers)				
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
Time to complete task in Wiimote	5:27 mins	4:26 mins	3:41 mins	3:30 mins	3:44 mins	5:21 mins	7:07 mins	4:03 mins	4:15 mins	14:28 mins
Time to complete task in Wiimote with feedback	4:42 mins	6:32 mins	6:51 mins	4:17 mins	3:50 mins	7:40 mins	5:23 mins	4:34 mins	2:22 mins	7:59 mins
Time to complete task in 3ds Max	10:10 mins	15:25 mins	10:43 mins	8:14 mins	11:13 mins	15:03 mins	11:24 mins	6:48 mins	8:10 mins	10:13 mins

Table 1 Time to Complete Task (Before After)

Ten subjects tested in our system. The first group is normal users who are subject 1 to subject 5. They are not familiar with 3D software. Only subject 5 has some experience in Maya. Subject 4 and Subject 5 have some experienced in playing game with Wiimote but they rarely play it. However the other in this group has never used Wiimote before. The second group is designers who are expert in 3D software. Subject 6 is expert in Rhinoceros 3D. Subject 7 is a FORM Z user. Subject 8 and subject 9 are

professional in 3ds Max. However subject 9 is also able to do AutoCad. Subject 10 is an expert SolidWorks user. Only subject 10 is familiar with Wiimote. Subject 6 and subject 7 have never played Wiimote. Subject 8 and subject 9 have some experience in Wiimote but they play Wiimote about one time a month.

All subjects were given a task to do and we measured elapsed time to terminate task. We compared elapsed time that subjects spent in doing task by Wiimote, Wiimote with force feedback, and general 3D software using mouse and keyboard. From the graph, we found that subjects operate in our system quicker than normal 3D software as displayed in figure 35.

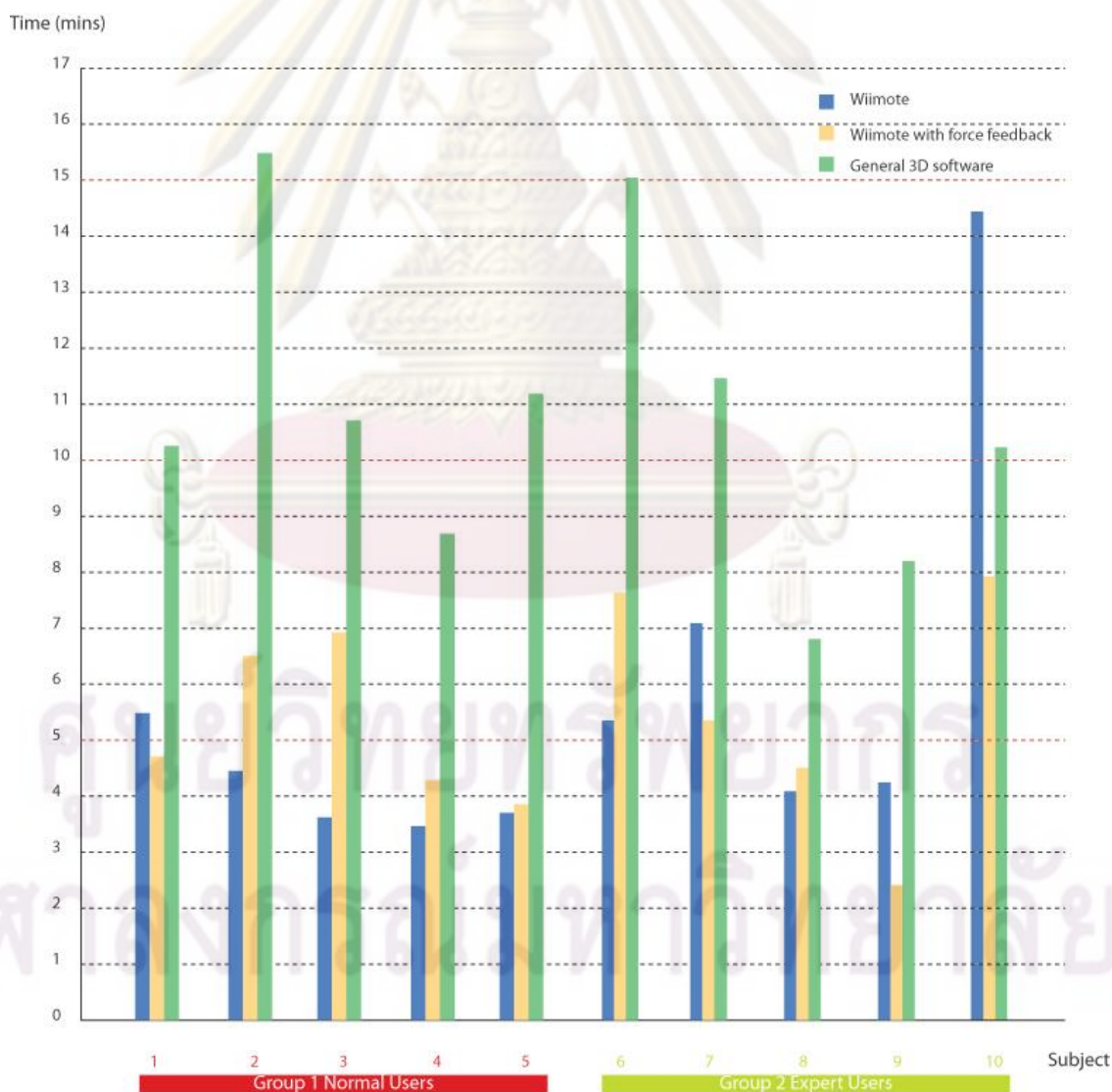


Figure 35 Elapsed Time Graph

From table 1, subject 10 took 7 minutes and 59 seconds which was the longest time to finish task in Wiimote. This subject also spent the longest time in Wiimote with force feedback which was 14 minutes and 28 seconds. This subject was confused in our system so he created and deleted many times as described later in this chapter. In contrast, subject 4 took 3 minutes and 30 seconds which was the best performance time in Wiimote. Subject 9 finished task in 2 minutes and 22 seconds which is the shortest time in Wiimote with force feedback.

	Time to Complete task(mins)		
	3ds Max	Wiimote	Wiimote with Force feedback
Group I Normal Users	11 mins 9 secs	4 mins 10 secs	5 mins 14 secs
Group II Designers	10 mins 20 secs	5 mins 12 secs	6 mins 24 secs
Overall	10 mins 44 secs	4 mins 41 secs	5 mins 49 secs

Table 2 Average Time to Complete Task

From the experiment, there are two outliers. One is in Wiimote and another is in Wiimote with force feedback. In Wiimote, subject 10 spent time dramatically longer than others. On the other hand, subject 9 completed task within a little time in Wiimote with force feedback system. These two data are tremendous different from the others so we do not include these two data to calculate the average time. Therefore the average times in Wiimote and Wiimote with force feedback are ninety percent average time. From table xxx, the least average time is in Wiimote system which is about 4 minutes and 41 seconds. The average time for Wiimote with force feedback is 5 minutes and 49 seconds. Finally, the most average time to complete task is 10 minutes and 44 seconds in general 3D software using mouse and keyboard.

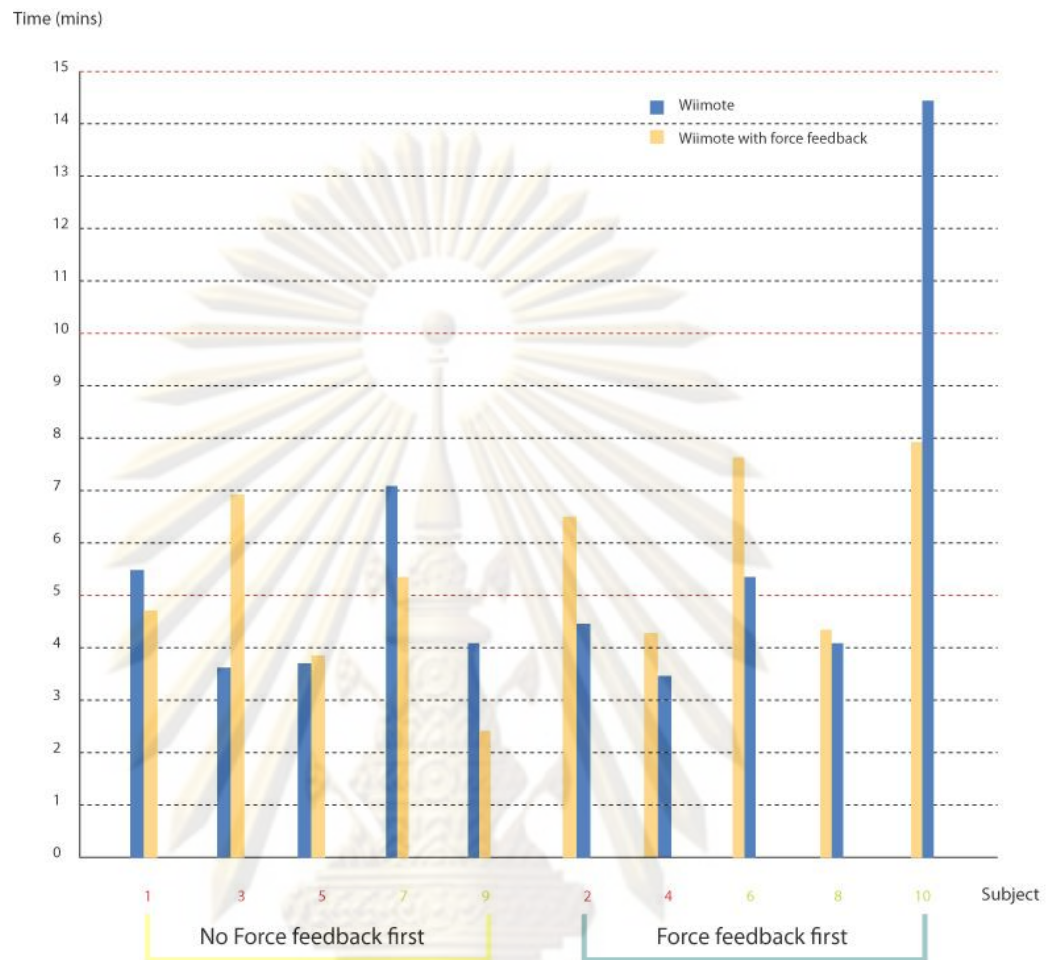


Figure 36 Elapsed Time Related to Sequence of Using Wiimote

Although most subjects feel that force feedback helps them to do their task, there is no strong evidence indicates that they operate their task quicker than using Wiimote without force feedback. However if we rearrange the elapsed time graph in the sequence of system which is used by subjects, we can see some pattern related to the learning curve of system (Figure 36).

Five subjects used Wiimote before using Wiimote with force feedback. In contrast, the other five subjects did their task by Wiimote with force feedback first as described in figure 36. This graph shows that seven subjects finished their task quicker in the second times. Subject 5 spent time to do task in the second time just a little more than the first time. Only two subjects finished their task in the second time longer than the first time. Subject 3 did wrong rotation so he has to delete and creating object again. Subject 10

confused in rotation. As a result of object rotated around its own axis. For example, if subject rotates object in x axis 90 degrees, the rotation in y axis now is roll or rotation in z axis. Thus this subject confused in this and spent a lot of time trying to understand this by creating, modifying and delete object many times.

	Group I (Normal Users)					Group II (Designers)				
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
Force feedback (Helping)	Good 4	Normal 3	Good 4	Normal 3	Normal 3	Good 4	Good 4	Normal 3	Good 4	Good 4
Awareness of Force feedback	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Awareness of Event trigger Force feedback	All Events	No	Select Obj.	No	No	All Events	Menu, Cutting, Copy	No	Menu, Cutting	Menu

Table 3 The Relationship between Force feedback and Users' awareness

Six subjects report that force feedback helps them to do their task. For example, they know how many object they create or copy because Wiimote vibrates every time object is created in scene. This data is shown as a confirmation feedback to reduce users' confusion. From table 3, data is collected from interview and questionnaires. This data indicates that there is a relationship between awareness of force feedback from Wiimote and its helpfulness. As subjects who not only notice the vibration of Wiimote but also know which state it will vibrate, will respond to questionnaire that force feedback of Wiimote is useful. Hence, we can conclude that awareness of force feedback is

significant in using this system. Most users who observe that which operations Wiimote will send feedback to them, will employed this feedback in such a useful way.

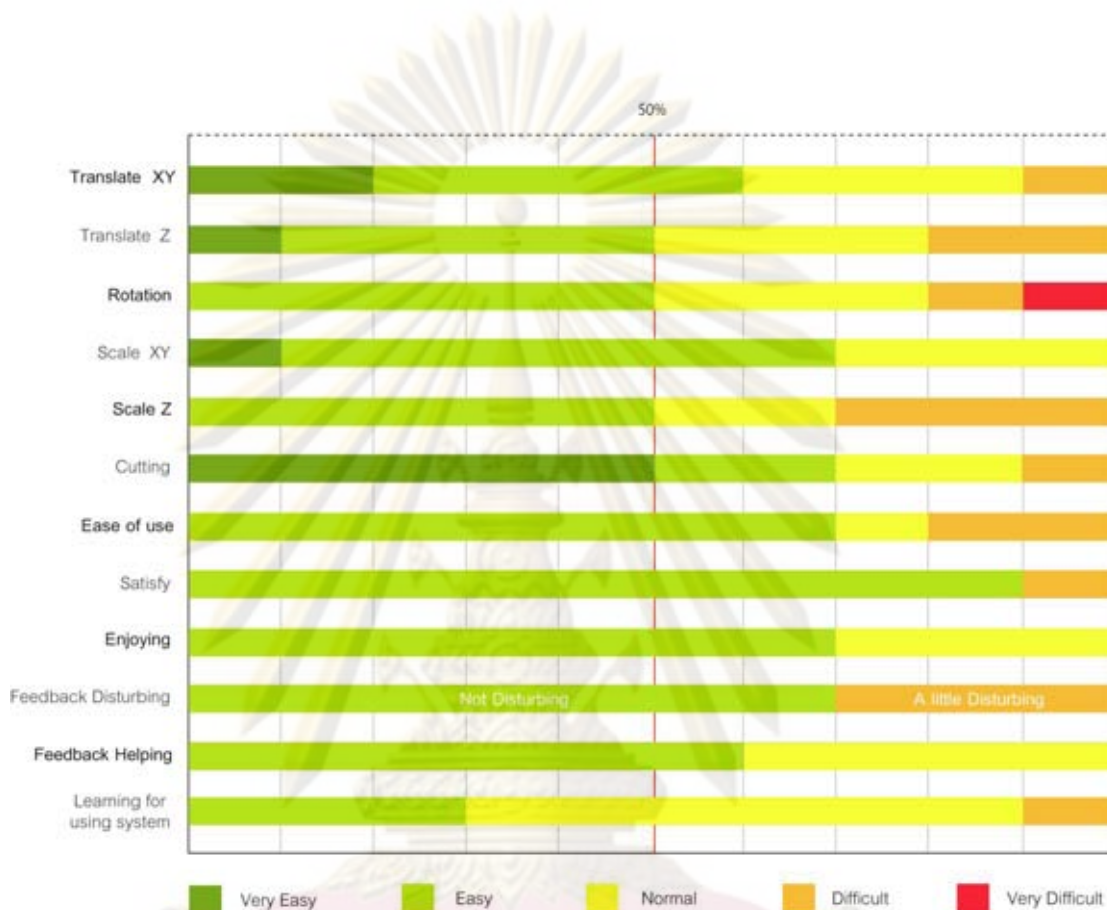


Figure 37 Questionnaire Results

This graph shows the answer of questionnaire by subjects. From graph above, the result shows that all of operations in this system are easy to use. Only one subject feel that translate in xy axis was difficult because this subject confused with direction button. This subject justified that direction button should be used to translate object. For translation in z axis and scale in z axis, most subjects who feel it was difficult report that they were more familiar with left to right control than moving in and out. In addition, the limitation of hardware which could not constantly detect both LEDs sometimes made a trouble for translating and scaling in z axis. Furthermore, subjects also indicated that

they did not know which direction object was scaled while they were scaling object in z axis.

Ten percent of subjects or one subject conveyed that rotation was difficult. This subject explained that he was not convenient to rotate object in x axis by pitching Wiimote up and down. Another ten percent who was subject 10 confused about rotation axis as described in above section. Thus this subject justified that this operation was very difficult. Moreover, this subject also required precision method for modifying object. For example, subject asked how to rotate only ten degrees in this system. This system does not provide a very accurate method because we just want a tool which can roughly sketch or model via 3D input device. Therefore this subject unsatisfies our system.

Only ten percent identified that cutting operation in this system was difficult to use. Subject 10 explained that the plane for cutting was able to see in two lines which were the edges of plane in front and back. This subject convinced that for cutting more precisely, it should see only a line for cutting object.

Thirty percent of subjects described that the force feedback disturbed them a little. Two subjects were frightened by the force feedback of Wiimote at the first time. Then they were familiar of it. One subject hesitated to continue doing his task and stopped for a while. As he described that he did not know he could continue or had to wait until the vibration finished.

From interview and observation, we also find that some subjects immerse to the system. They move their body according to their movement of Wiimote similar to playing game. Some subjects prefer to rotate object only one axis at a time because it is quite sure that they will not lose the direction. One Subject likes this kind of input because he is left-handed user. Unlike the mouse, Wiimote is designed for both right-handed users and left-handed users. Therefore this subject does not have to adapt anything to use it.



In summary, ninety percent of subjects satisfy our system. They enjoy using our system because of its ease of use and intuitive to use. Nevertheless, from observation and interview, there are still some problems which have to be improved.

- LEFT button is designed for changing menu. However many subjects accidentally pressed it while they tried to rotate object.
- Subjects find that it is difficult to move or rotate object a little. As the Wiimote is wireless and there is no support area like mouse and keyboard. Thus system should provide some method to refine 3D object position and orientation.
- There are two circles which are beside the cursor. These circles help subjects to translate and scale in z axis. In addition, they also aid subjects that IR LEDs are still in the range to operate cursor. Nonetheless, some subjects feel annoyed them. Therefore these circles should be less obvious than they are now.
- Every time subjects click an A button to select object. Object will be moved to the center of cursor. Hence, it is difficult to arrange object as subjects want.
- Many subjects ask for a grid to reference while they are manipulating object.
- Some subjects ask for changing color of objects.
- Object is difficult to operate, if it is near the edge of the screen.

## Chapter V

### Conclusion and Suggestion

#### 5.1 Conclusion

In this system, we study methods to communicate between Wiimote and computer which are hacked by many developers. The hardware requirements in this project are simple. We employ only bluetooth adapter and simple DIY wireless sensor bar. For communication between Wiimote and computer, there are many APIs providing a method to do this. Our system employs WiiFlash API to connect Wiimote with Adobe Flash application via Bluetooth wireless technology. Then we transfers 6 DOF data from Wiimote to Flash. Input data from Wiimote is smooth and used to control 3D objects which are rendered by Papervision3D. The result is 3D interactive system which is inexpensive, easy to find and responds to Wiimote in real time. Six DOF input data from Wiimote are employed to translate, to rotate, to scale and to cut 3D objects. The wireless 3D input shows its potential in 3D task as it is intuitive and eases of use. The result confirms that direct manipulation in tangible interface proves its ease and its effectiveness as in Surface Drawing project [6] and Tangible + Virtual project [7]. Our system enhances users' performance time to create 3D model by rotating, scaling, translating and cutting. In addition, most users satisfy and enjoy using it. This system not only provides six DOF data but it also provides force feedback. Although there is no evidence that it enhances users' performance time, it aids users to confirm their action and tell some state of system to them. Therefore it reduces users' confusion. As in Tangible3D [9] conveys that complex geometry or large number of polygon is difficult to manipulate without haptic feedback. However force feedback is the second priority feedback. Many users always focus only on visual feed back and do not notice the force feedback role. We find that the force feedback will be useful, if users realize this information and know when it will occur. Hence system should provide some clue to make them realize this information. Although we do not address to create rich detail 3D

model in this system, we can count that the drawback of this system is precision. Wiimote is wireless and it can freely move unlike mouse which has an area to support. Hence it is difficult to move a little or adjust object a little. Nevertheless, the direction buttons have potential to use in this issue. In brief, this project proposes a tool which can create roughly 3D model quicker. It is not expensive and it is intuitive and easy to use. Therefore it has a potential to bring designers to sketch roughly 3D model in digital. We hope that it will bypass the process of sketch or making a model in physical which have to transform it later in digital.

## 5.2 Suggestion

This system is motivated by wireless 3D input Wiimote. It shows a new possibility to create 3D model which is able to send 6 DOF data. Although most users satisfy this system, it still in the beginning stage of development. From the experiment, there still are some problems as described below which should be technically improved in the future.

- There is still IR LEDs detection problem in our system. In real sensor bar, there are five IR LEDs per each side. However in our system, there are only four LEDs per each side. Thus if we increase number of LEDs per each side, the performance of IR sensor might be better.
- Two circles indicate IR LEDs position can be faded or invisible. Our system is able to use force feedback to warn users that IR LEDs are out of range. Therefore these two circles should visible only while users want to do some operation related to z axis.
- System should store the position of Wiimote input at least five frames. When system fails to detect one LED, it should use these five frames input to analyse more accurately.
- At present, some users still confused to rotate object in this system as described in results section. Algorithms to rotate object should be changed to quaternion. Thus there will not be a problem of changing axis and gimbal lock after object is rotated. In addition, there should be some visual cue to visualize

which axis and direction users are going to rotate. This visual cue will increase the intuitive of rotation object.

- This system not only should add grid for reference but it also has to add text label to show parameter of object. This text label is an important issue especially to know the exactly proportion while they are scaling object.
- LEFT button should be changed to do something related to rotate object.
- There should be an axis of object showing when object is selected.
- System should provide a method to adjust model more precision.
- System should provide top, front, side viewport for easing users while operating their task.
- From this study, it indicates that some users focus only on visual until they do not notice the vibration of Wiimote. Thus there should be a visual feedback for increasing awareness of force feedback. For example, screen is blinked while users are doing something that trigger the force feedback.
- Force feedback is able to employ as a haptic feedback. It is able to provide a little or strong vibration while cutting along object. Thus this haptic feedback can create a feeling of object's material or users' force. For example, if users cut a metallic object, strong vibration will be applied to give a sense of stiffness. The level of force feedback depends on how long it vibrates. Hence, to implement the level of force feedback, we will set an interval for Wiimote to adjust its level of vibration.
- Users are able to know the direction of scale or move in z axis by adding some icon to show the direction.
- This system can support nunchuck which is controller attached to Wiimote. Users are able to use this nunchuck to control camera in this system. Therefore they can use both hands to operate their task quicker.

This project focuses only on using wireless 3D input device to create and modify 3D model. The result addresses the potential to model 3D via Wiimote. Furthermore, there

also are many possibilities to extend this project which we hope to study further. As Wiimote is wireless input device, users can freely move it. Thus we can study on how users create freeform from movement of Wiimote. Wiimote has a potential to bring designers to sketch roughly 3D model in digital, if system provides a method to draw a freeform 3D model. We hope that it will bypass the process of sketch or making a model in physical which have to transform it later in digital." As in Free Hand Form Generation project [8] state that three dimensional, direct, digital design system is possible and will be a common technology available to concept design. Another topic which is also interested is to add more modifier operation like beating or scooping out 3D object using Wiimote. Finally, this system has a potential to support multi user. Moreover Wiimote is wireless so it is suitable for large projector or table top display. Hence it can be used in collaboration design task. We expect that it will enhance communication which is a significant issue in collaboration design. We hope it will overcome a lot of limitations of mouse to create 3D model.



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## References

- [1] Hewett, Baecker, Card, Carey, Gasen, Mantei, Perlman, Strong and Verplank, CHAPTER 2: Human-Computer Interaction, (ACM SIGCHI Curricula for Human-Computer Interaction, 1992, 1996). p.5.
- [2] Myers B.A. A Brief History of Human Computer Interaction Technology. ACM interactions. 5, 2 (1998) : 44-54.
- [3] Dix A., Finlay J., Abowd G. and Beale R. Human-Computer Interaction. New York, London : Prentice Hall Europe, 2004.
- [4] Barfield W., Furness T. Virtual Environments and Advanced Interface Design. New York, Oxford : Oxford University Press, 1995.
- [5] Preece J., Rogers Y., Sharp H., Benyon D., Holland S., Carey T. Human-Computer Interaction. England, New York, Amsterdam : Addison-Wesley, 1994.
- [6] Schkolne S., Pruetim., P. S. Surface drawing: Creating organic 3d shapes with the hand and tangible tools. In Proc. of CHI. (2001) : 261–268.
- [7] Schkolne S., Ishii H. Schroeder P. Tangible+ virtual = a flexible 3d interface for spatial construction applied to DNA. California Institute of Technology. (2002).
- [8] Diniz N., Branco C. An Approach to 3D Digital Design Free Hand Form Generation. Proceedings of the Eighth International Conference on Information Visualisation. (2004).
- [9] Kim H., Albuquerque G., Havemann S., Fellner D.W. Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction. Computer Graphics Forum. (2005).
- [10] Lee J.C. Hacking the Nintendo Wii Remote. IEEE Pervasive Computing 7 (July 2008): 39-45.
- [11] Sosuwan K., Wireless Sensor Bar for Nintendo Wii Console, Hobby Electronics 161 (November – December 2007):22.
- [12] Ulloa C., Grden J., Hauwert R., Knip T., Papervision3D [Online], 2006. Available from: <http://www.papervision3d.org> [2009, May].
- [13] Winder J., Tondeur P. Papervision3D Essentials. Birmingham : Packt, 2009.

- [14] Ebert J., Imbert T., WiiFlash [Online], 2007. Available from :  
[http://wiiflash.bytearray.org/?page\\_id=2](http://wiiflash.bytearray.org/?page_id=2) [2007, April].
- [15] Rosenkvist J.P. Headtracking using a Wiimote. Master's Thesis, Department of Computer Science University of Copenhagen, 2008.
- [16] Granberg C. Programming an RTS Game with Direct3D. Boston : Thomson, 2007.
- [17] Eberly D., Clipping a Mesh Against a Plane [Online], Available from :  
<http://www.geometrictools.com/> [2008, March].
- [18] Dunn F., Parberry I. 3D Math Primer for Graphics and Game Development. Texas : Wordware, 2002.
- [19] Croll M. A New Approach to Cutting Tetrahedral Meshes. Master's Thesis, Department of Computer Science Old Dominion University, 2007.



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Appendices

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## Appendix A

### Questionnaire Results

	Group I (Normal Users)					Group II (Designers)				
	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10
<b>Translate XY</b>	Easy	Normal	Difficult	Very Easy	Normal	Normal	Easy	Very Easy	Easy	Easy
<b>Translate Z</b>	Easy	Difficult	Normal	Easy	Normal	Normal	Easy	Very Easy	Easy	Difficult
<b>Rotate</b>	Normal	Easy	Difficult	Easy	Normal	Easy	Easy	Normal	Easy	Very Difficult
<b>Scale XY</b>	Easy	Easy	Easy	Very Easy	Normal	Normal	Easy	Easy	Easy	Normal
<b>Scale Z</b>	Easy	Difficult	Easy	Easy	Easy	Normal	Difficult	Normal	Easy	Difficult
<b>Cutting</b>	Very Easy	Easy	Normal	Very Easy	Easy	Very easy	Very easy	Normal	Very easy	Difficult
<b>Ease of use</b>	Easy	Easy	Difficult	Easy	Easy	Easy	Easy	Normal	Easy	Difficult
<b>Satisfy</b>	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Not Satisfy
<b>Enjoying</b>	Normal	Normal	Enjoy	Enjoy	Enjoy	Enjoy	Enjoy	Enjoy	Enjoy	Normal
<b>Force feedback (Disturb)</b>	No	No	Little Disturb	No	No	No	Little Disturb	No	Little Disturb	No
<b>Force feedback (Helping)</b>	Good	Normal	Good	Normal	Normal	Good	Good	Normal	Good	Good
<b>Learning for using this system</b>	Easy	Normal	Normal	Normal	Normal	Normal	Easy	Normal	Easy	Difficult

Table 4 Questionnaire Results

Appendix B  
Sketch from Designer Group

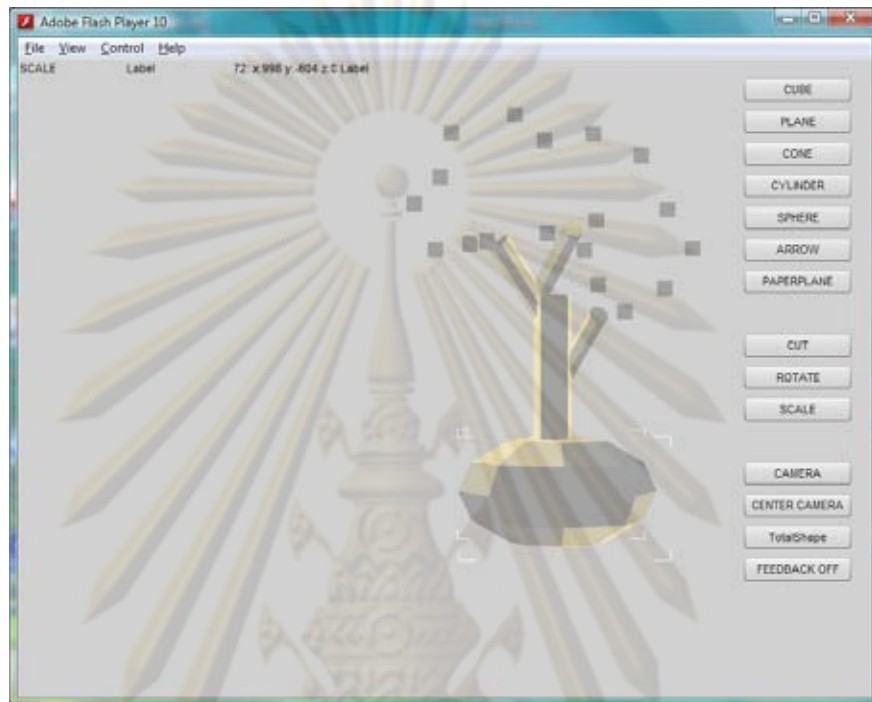


Figure 38 Sketch from Subject 6

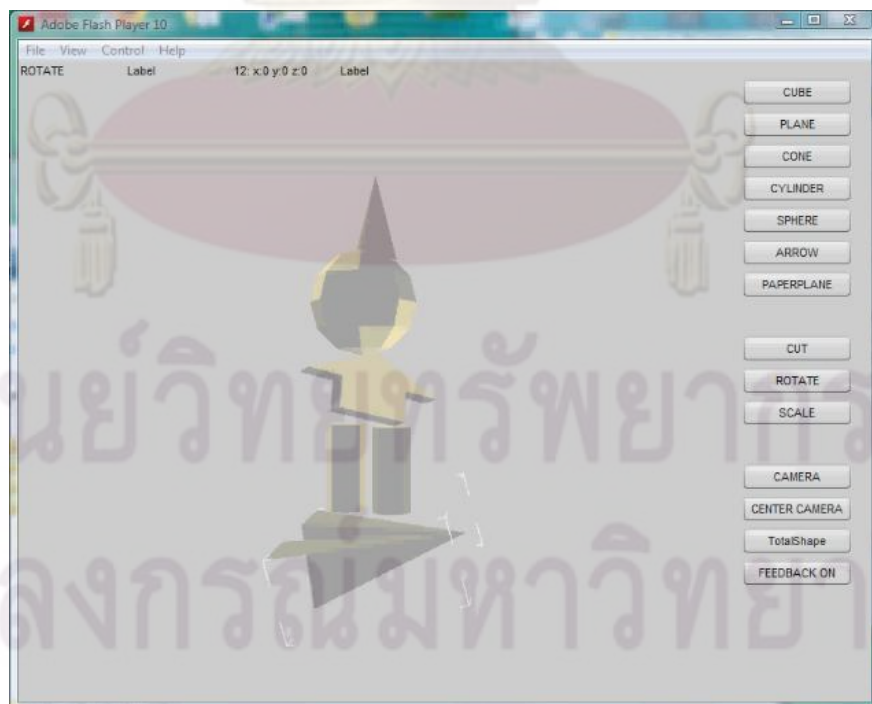


Figure 39 Sketch from Subject 7

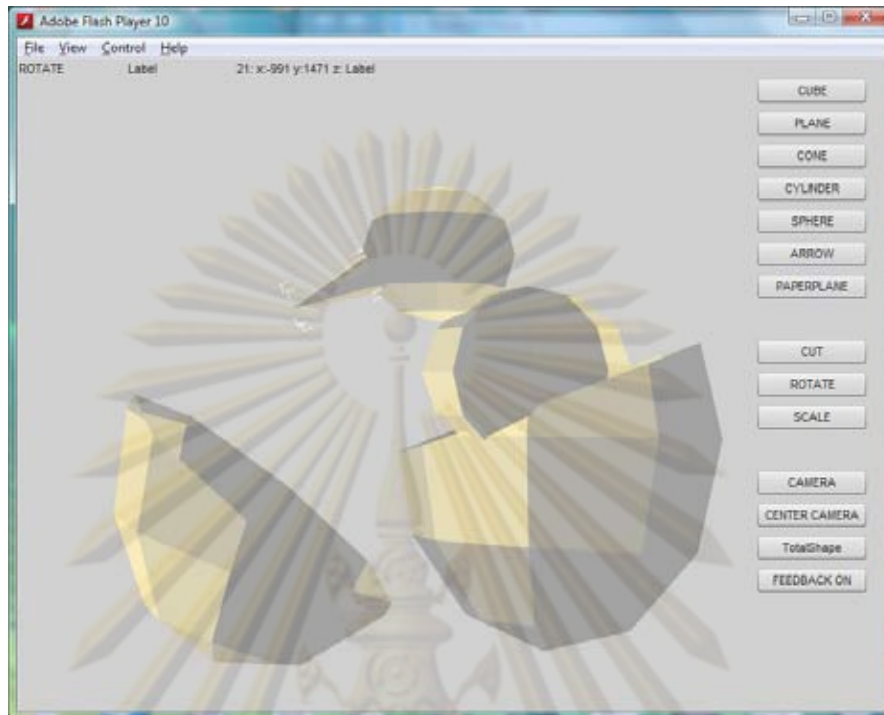


Figure 40 Sketch from Subject 8

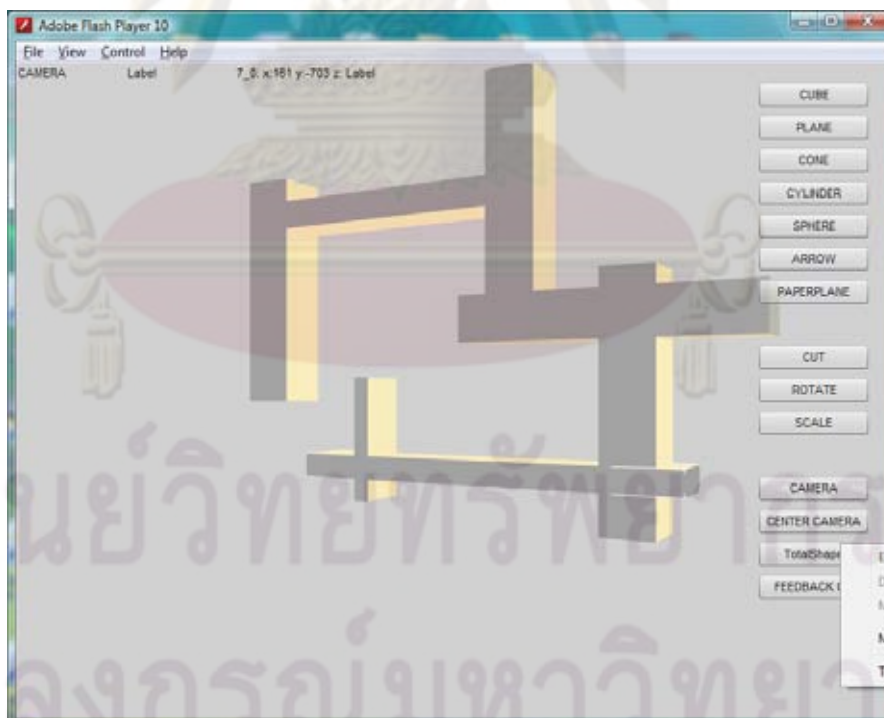


Figure 41 Sketch from Subject 9

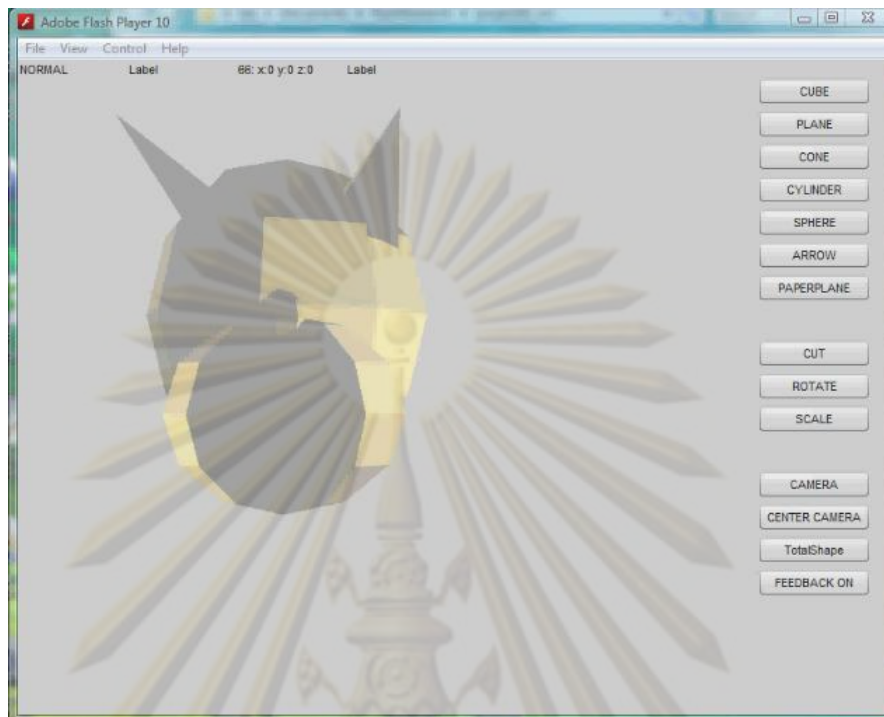


Figure 42 Sketch from Subject 10

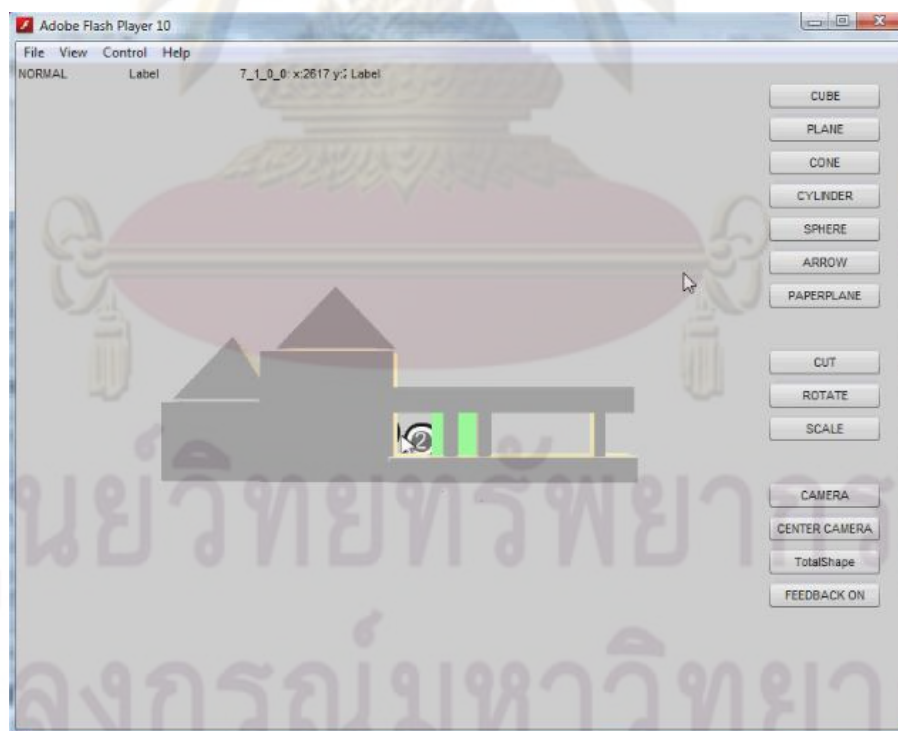


Figure 43 Sketch from Subject in Preliminary Test

## Appendix C

## Questionnaire

ข้อมูลส่วนตัวของท่านจะถูกเก็บเป็นความลับ และข้อมูลที่ได้จากการทดลองจะถูกนำไปใช้ในการศึกษาเท่านั้น

ชื่อ ..... นามสกุล .....

เพศ  ชาย  หญิง

อายุ  น้อยกว่า 20  20-25  26-30  31-35  มากกว่า 35

1. ท่านอยู่ในสายงานใด

สถาปัตยกรรม  อินทีเรีย  กราฟฟิคดีไซน์  ออกแบบผลิตภัณฑ์

อื่นๆ (โปรดระบุ).....

2. ท่านใช้โปรแกรมใดในการออกแบบ หรือขึ้นโมเดล 3 มิติ (ถ้าไม่ได้ใช้ซอฟต์แวร์สามมิติ โดยปกติใช้ซอฟต์แวร์ใด)

3ds Max  Maya  SketchUp  Blender  Softimage

อื่นๆ (โปรดระบุ)

.....

3. ท่านใช้โปรแกรมขึ้นโมเดล 3 มิติ บ่อยแค่ไหน

ทุกวัน  2-3 วัน/ครั้ง  สัปดาห์ละครั้ง  เดือนละครั้ง  น้อยกว่าเดือนละครั้ง

4. ท่านเล่นเครื่องเล่นนินเทนโด ที่ใช้วีโมตบ่อยแค่ไหน

ทุกวัน  2-3 วัน/ครั้ง  สัปดาห์ละครั้ง  เดือนละครั้ง  น้อยกว่าเดือนละครั้ง

5. ท่านคิดว่าการ translate ในแกน xy โดยใช้วีโมตเป็นอย่างไร

ยากมาก  ยาก  ธรรมดา  ง่าย  ง่ายมาก

6. ท่านคิดว่าการ translate ในแกน z โดยใช้วีโมตเป็นอย่างไร

ยากมาก  ยาก  ธรรมดา  ง่าย  ง่ายมาก

7. ท่านคิดว่าการ rotate โดยใช้วีโมตเป็นอย่างไร

- ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

8. ท่านคิดว่าการ scale ในแกน xy โดยใช้วีโมตเป็นอย่างไร

- ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

9. ท่านคิดว่าการ scale ในแกน z โดยใช้วีโมตเป็นอย่างไร

- ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

10. ท่านคิดว่าการตัดวัตถุโดยใช้วีโมตเป็นอย่างไร

- ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

11. ท่านคิดว่าการใช้ระบบนี้ในการโมเดลตามที่ท่านได้ทำมาเป็นอย่างไร

- ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

12. ท่านรู้สึกพอใจกับการใช้ระบบนี้หรือไม่ เพราะเหตุใด

- พอใจมาก     พอใจ     ธรรมดา     ไม่พอใจ     ไม่พอใจมาก

.....  
 .....

13. ท่านรู้สึกสนุกสนาน หรือเพลิดเพลินในการใช้ระบบนี้มากแค่ไหน

- สนุกมาก     สนุก     ธรรมดา     น่าเบื่อ     น่าเบื่อมาก

14. ระบบการสั่งของวีโมตรบกวนท่านหรือไม่ อย่างไร

- รบกวนมาก     รบกวนพอควร     รบกวนเล็กน้อย     ไม่รบกวน

.....  
 .....

15. ท่านคิดว่าระบบการสั่นของตัววีโมตมีส่วนช่วยให้ท่านทำงานกับระบบนี้ได้ดีขึ้นหรือไม่ อย่างไร

ดีขึ้นมาก     ดีขึ้น     ธรรมดา     แย่ลง     แย่ลงมาก

.....

.....

16. ท่านคิดว่าการเรียนรู้เพื่อใช้งานในระบบนี้เป็นอย่างไร

ยากมาก     ยาก     ธรรมดา     ง่าย     ง่ายมาก

17. ข้อเสนอแนะเพิ่มเติม (ปัญหาเพิ่มเติม, ควรเพิ่มอะไรลงไปในระบบ, ควรใช้กับงานแบบไหน, ฯลฯ)

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ศูนย์วิทยทรัพยากร  
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## Appendix D

### Paper Conferences

The following paper is the paper in the title of Wiimote Interface for Cutting and Folding 3D Digital Model. This paper has been presented at the 5<sup>th</sup> International Joint Conference on Computer Science and Software Engineering (JCSSE2008) between May 7-9, 2008.



ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย



## Wiimote Interface for Cutting and Folding 3D Digital Model

Sutas Chaisinanantkul and Pizzanu Kanongchaiyos

Department of Computer Engineer, Faculty of Engineer, Chulalongkorn University  
Phayathai Rd., Patumwan, Bangkok 10330, THAILAND  
[sutas.c@student.chula.ac.th](mailto:sutas.c@student.chula.ac.th) , [pizzanu@cp.eng.chula.ac.th](mailto:pizzanu@cp.eng.chula.ac.th)

### Abstract

*This paper proposes an interface to use three dimensional (3D) input device which is wiimote to modeling 3D objects especially in architectural design. The advantage of using Wiimote is that it is able to have multiple Wiimote connection. Hence users can use it to design and modeling 3D collaborates with their colleague. Comparing with the architectural physical paper model, this system offers cut and fold method to manipulate 3D object. It is wireless, intrusiveness, intuitive and supporting multi user. In brief, this paper argues that 3D input device will ease and enhance 3D modeling tool in design process.*

**Key Words:** Interface, 3D modeling, Input Device, Wiimote

### 1. Introduction

Three dimensions modeling system is very useful in many field. Especially in design, many users, such as architects, industrial designers and artists, always use this system to visualize or create their work. Though, this system aid designer to do their work, they found that it is not intuitive to use. One of the reasons of this is most input device in 3D program using mouse and keyboard which, is 2D control device. Therefore to control 3D object, designers require additional steps to do to compensate the missing axis such as if they want to rotate 3D object in x and y axis, they have to choose icon for rotate and select the axis between x and y then move the mouse. These additional steps interrupt the flow of task while designers are working. Most designers find that it is difficult to use especially in the conceptual design because it interrupt their thinking. They have to focus on how they will manipulate 3D object rather than

pay attention on their design task or their thinking. Moreover, unintuitive interface require long learning curve to create 3D digital model. In addition, mouse and keyboard restrict the space and atmosphere to work for designers. They have to sit in front of the screen which in contrast, they prefer loosely space to work such as a sculptor want to stand and move around their work. As a result of these, it is not surprise that these 3D applications are used only for visualize their work or presentation. They are not considered to be an application for support creative thinking tool. Most designers still prefer to sketch on pencil and paper or work on physical model rather than using 3D modeling software. Therefore, the physical interface, which is employed 3D input device to be an input to create 3D model, is used in this project. In order to create intuitive interface support for collaborative and creative thinking design.

### 2. Related Work

Virtual Reality technology is employed to interact with 3D model as the interface is intuitive.



Figure 1. Surface Drawing : Creating Organic 3D Shapes with the Hand and Tangible Tools (2001)

For example, in Surface Drawing, this project also uses VR technology (Figure 1). Users have to wear data glove and Head Mounted Display to interact with this system. There are many tools for creating and interacting with 3D model. The first is the glove, user wears glove and presses the button between thumb and index finger to start a stroke. The second is tongs. This tool is for moving, scaling and rotating 3D model. The third is eraser which is made from silicone. Users can activate this tool by squeezing it then it will remove 3d object. The last one is magnet drawing which is for modify object. Although users easily create 3D digital model, it is not convenient to wear and the devices are expensive. The cables from gloves and other devices obstacle users to create or rotate object [1].

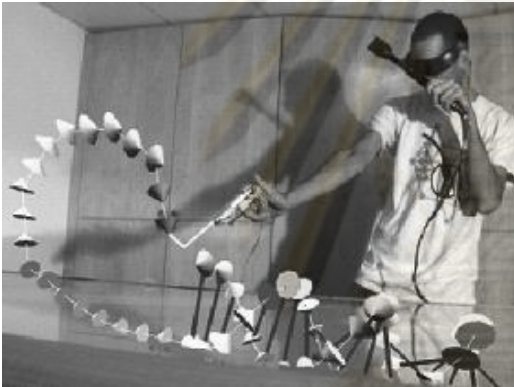


Figure 2. Tangible + Virtual = A Flexible 3D Interface for Spatial Construction Applied to DNA

This is the same as A Flexible 3D Interface for Spatial Construction Applied to DNA project (Figure 2). There are also many physical tools in this project. First, is a ray gun which is for picking point in space. It is modified from toy but, it is inserted motion tracker and sensor button to activate this tool. As construction DNA need to be precise selection within a dense volume such as user want to draw bond between base DNA. The purpose of this tool can compare with gluing object. Second, is a grip tool which controls 3D location. In addition, it is used to creating and cutting DNA. The last one is tongs which is used for manipulating object. DNA that is created can be local or global transformed and scaled by this tool. In brief, this project also uses device for specific purpose which is to model DNA [2].

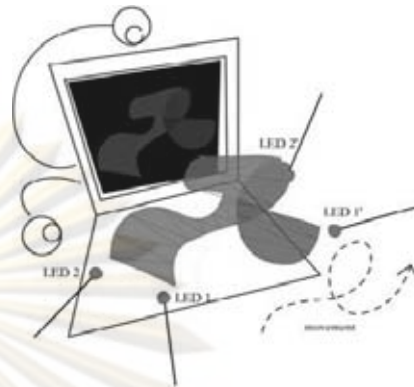


Figure 3. An Approach to 3D Digital Design: Free Hand Form Generation

Another technology which solves the wire problem, cost effective and comfortable is to use image processing and computer vision technology. In An Approach to 3D Digital Design, uses two web cameras to track two LEDs for creating surface. User moves their hands to draw 3D surface (figure 3). Two web cameras are used to track the position of LED's. One web camera is for tracking coordinate in x and y axis and another web camera is used for finding position in z axis [3].



Figure 4. Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction

In Tangible 3D, users have to wear four white paper rings (Figure 4). The polarize glasses covering with white paper is employed for creating stereographic to display 3D objects.

Tracking system is ease by black light. Gesture recognition also employs to manipulate 3D object [4]. These two projects are efficient way to interact with 3D object. However the limitation of tracking via image processing is that it is difficult in tracking multiple users. Wiimote which is 3D input device can solve this problem. It is inexpensive and intuitive to use. As it is motion sensor, it supports detecting level of force which users move it. This project offers new interface which users can create 3D model by cut and fold.

### 3. Concept of System

This system aims to create a 3D digital model tool which is inexpensive and the system device is easy to find. Moreover, the input device and interface will be intuitive enough for designers to use while they are designing. The system composes of two significant parts which are hardware and its interface.

#### 3.1 Hardware

In September 2007, a Nintendo Wii game console has sold more than 13 million consoles. This amount is vast over the number of Tablet PC sales. In addition, Wiimote communicates with the Wii via a wireless Bluetooth device (Figure 5). The Bluetooth Human Interface Device (HID) is basically based upon normal USB HID standard. Hence Wii Remote is able to communicate with computer and can be seen as a common input device for computer. Traditionally, the motion of Wiimote is sensed by 3D axis linear accelerometer (ADXL330). Moreover IR sensor is added to Wiimote because motion sensor is not accurate enough to control onscreen cursor. IR sensor which is in front of Wiimote will track the position of two beacons. These two beacons are in the Sensor Bar. Tracking of these two beacons, system can make more accurate of pointing information. Wiimote also have 12 buttons to send data, when they are pressed or released, to the host via HID input report. The ability to senses 6DOF data and its cost is inexpensive [5]. Therefore, in this project will employ Wiimote as an input device to modeling 3D object. In addition, other hardware devices which are Bluetooth adapter and the Sensor Bar will be used to make Wiimote communicate with the computer. In brief, the ability to senses 6DOF data and the its cost is

inexpensive. Therefore, in this project will employ Wiimote as an input device to modeling 3D object.

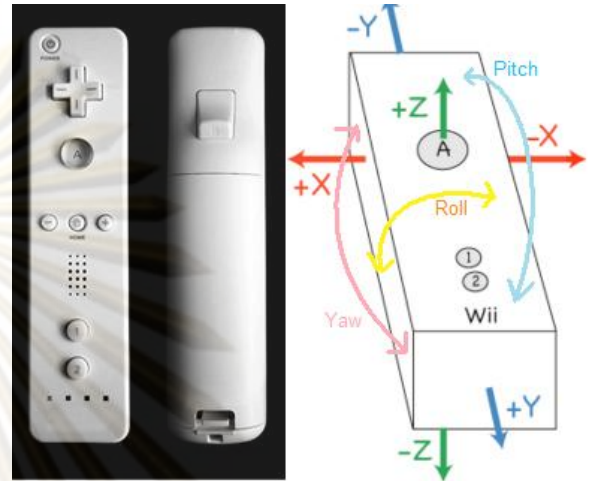


Figure 5. Wiimote

#### 3.2 Scenario of physical paper modeling

In order to understand 3D model, the scenario in the real world is used to explain (Figure 6). In conceptual design stage, architect or designer wants to see how their ideas form in 3D. They usually use paper which is rigid enough to model and it is frequently called schematic model. A rigid paper is cut and folds or rotates and glues it with other pieces to form their idea. Designers often mark, by using pencil to define the line which they want to cut, before they cut. The operation that designers cut can be divided into two ways. First is cut to separate one piece of paper into two. Then use the piece which they want to glue with other piece. Second is cut slightly enough to make rigid paper be able to fold. Another operation which designers may want to perform is to drill or to take inside piece out (Figure 7).

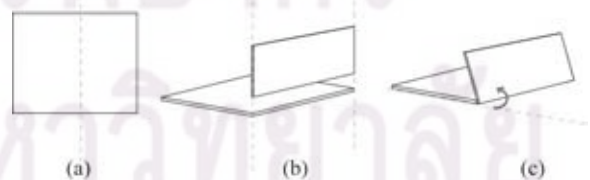


Figure 6. (a) Drawing the draft line before cutting. (b) Cutting, rotating and gluing with other piece. (c) Cutting and folding.

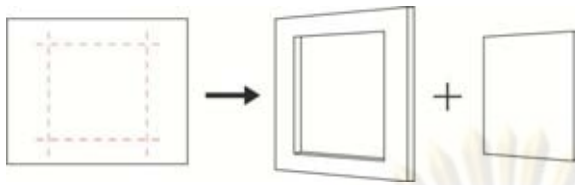


Figure 7. Cutting frame

### 3.2 Mapping operation to this system interface

Traditionally, the cutting operation in 3D software package is operated by using subtract Boolean operation. This is done by creating two forms and translates them into the position which designers want to subtract it. Next, they have to select the Boolean operation that they want. Then designers have to choose the main object. After that, select the other objects which they want to use them for subtracting with main object. In contrast, this interface is quite similar to the paper physical model. Most operation can be mapped directly to the physical method. As there are 12 buttons on Wiimote, this system employed pressing button combining with the movement and orientation of Wiimote to imitate the cutting operation in physical paper model. These following steps convey the mapping of interface from cutting physical paper model. First is to define the cutting line. In order to do this, this system will be designed to use the movement of Wiimote while pressing button A. This will create a line which is used to define for cutting 3D object. After that users have to confirm the cutting operation by pressing button B at the back of Wiimote. Second is to subtract Boolean operation. After users create multiple define cutting line. Then users pressed button B to cut. The system will detect and ask users to press on up directional button or down directional button. If users select up directional button, the system will cut according to the line users create. On the other hand, if users choose down directional button, system will find the intersection of coordinate of cutting line and use this shape to subtract it from the main 3D object. In order to select 3D object, the left directional button will be mapped to be the same as left click of mouse. The same as left directional button, the right directional button will be used as a right click to choose additional menu. The home button will be used for moving pivot point of 3D shape. Although after cutting the pivot is moved to the edge near other 3D object for preparing to fold it or rotate it, sometimes users might want to rotate with different pivot

position. Hence this can be an optional for users. Due to the limitation of angle to turn wrist, the plus and minus button is used to weight the angle while designers need to rotate 3D object at once. Otherwise users have to deselect object after they reach the limited of their wrist and turn back their wrist to normal position. Then select 3D object to rotate again. If designers press Plus button, it will add the weight variable to increase angle such as when they turn the Wiimote the 3D object will be rotated more than normal corresponding to the turning wrist of users. In contrast, pressing minus button will decrease rotation angle when users turn Wiimote. The last two buttons which will be used are One button and Two button. Normally, they are used to send data for setting up connection via Bluetooth. In this interface, these two buttons will be employed as undo and redo operation. One button will be an undo operation and Two button will be a redo operation.

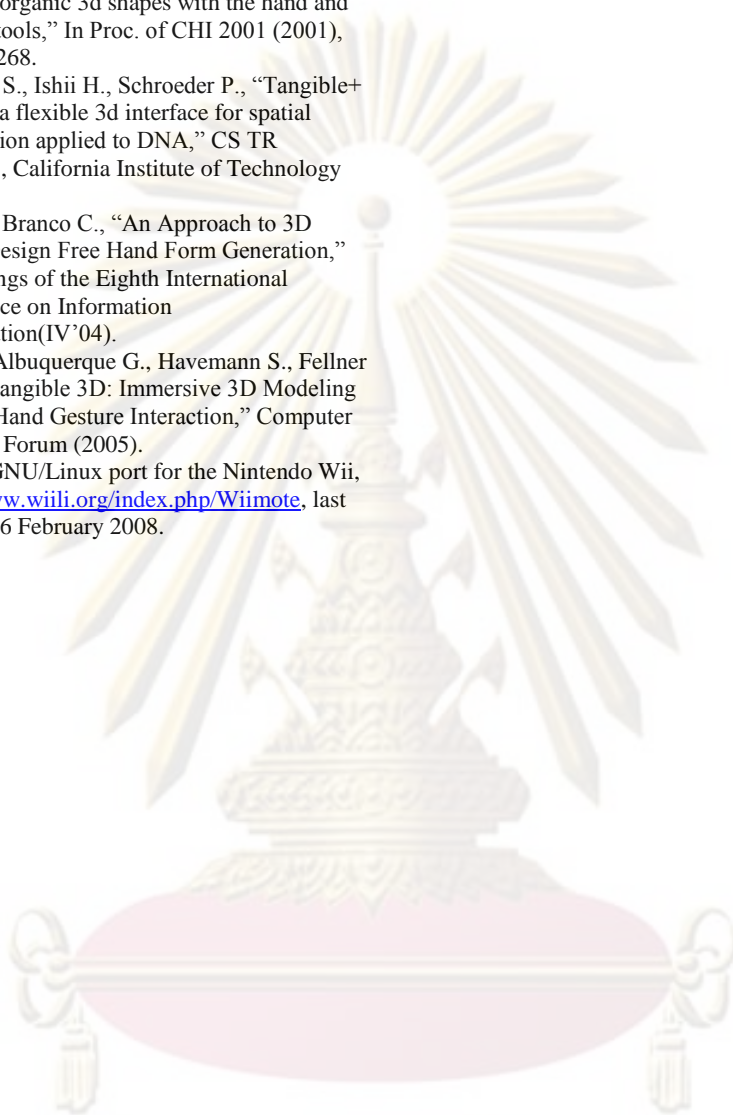
In summary, the button operations will be mapped depending on frequency of use. If the operation happens quite often, it will be put in the area around the button A which is the center of operation. The buttons on the face is pressed by thumb but only the button B at the back is pressed by index finger. As a result of mapping frequency operation with location of button, it should make a better performance because users spend less time to locate their thumb to press the button. The directly mapping of real physical interface into this interface tend to show that users are able to intuitively use this system and spend less time for learning to model 3D in this system.

### 4. Conclusion

The result of mapping physical paper cutting model to this Wiimote interface, is shorten the operation that users want to do in normal 3D software packages which use mouse and keyboard. Designers is able to intuitively control 3D object by moving and rotating Wiimote like they move and rotate object in the real world. Furthermore, as the number of action to accomplish task in cutting is decreased. This can be concluded that designers perform their task in design fluently. Their thinking will not be interrupted by additional operation in normal 3D package.

## 5. References

- [1] Schkolne S., Pruetim P.S., “Surface drawing: Creating organic 3d shapes with the hand and tangible tools,” In Proc. of CHI 2001 (2001), pp. 261–268.
- [2] Schkolne S., Ishii H., Schroeder P., “Tangible+ virtual = a flexible 3d interface for spatial construction applied to DNA,” CS TR 2002.011, California Institute of Technology (2002).
- [3] Diniz N., Branco C., “An Approach to 3D Digital Design Free Hand Form Generation,” Proceedings of the Eighth International Conference on Information Visualisation (IV’04).
- [4] Kim H., Albuquerque G., Havemann S., Fellner D.W., “Tangible 3D: Immersive 3D Modeling through Hand Gesture Interaction,” Computer Graphics Forum (2005).
- [5] WiiLi, a GNU/Linux port for the Nintendo Wii, <http://www.wiili.org/index.php/Wiimote>, last visited: 16 February 2008.



ศูนย์วิทยทรัพยากร  
จุฬาลงกรณ์มหาวิทยาลัย

## Biography

Mr. Sutas Chaisinanantkul graduated in bachelor degree from faculty of Architecture at Chulalongkorn university in 2000. Then I have studied in MSc. Computer Science from faculty of Computer Engineering since 2006. My current interests include interaction design, computer graphics, information visualization, and design and computation. At present I work in the field of web and mobile development supported by telecommunication company in Bangkok.



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