Using Hand Movement System to Operate 3D Objects in Virtual Environment

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Abstract. *This study integrates infrared distance measuring sensors and applies wrist rotations and hand movements to replace the space operations of conventional mouse and Data Glove. Through an array of infrared distance measuring devices, the position and direction of the hand in the space can be precisely detected, allowing designers to control 3D design objects intuitively in virtual spaces. The infrared distance measuring device adopted in this study has the effective test distance about 40 cm, with the precision range between 4 ~ 30cm, which is compatible with general hand movements. This device is expected to provide designers a more economical way to achieve intuitive operations in virtual spaces, as well as an intuitive way to explore virtual environments.*

Keywords. *input device, hand movement, human-computer interaction, infrared distance measuring, virtual environment*

Introduction

Before the invention of computers, paper, pen and physical model were important media used in the design process (Rowe, 1987). The introduction of "Computer-Aided Design (CAD)" allows designers to reduce the consumption of time and resources in the design process, and provides a wider range of design media. However, new media have brought significant influence on the traditional design (Ouyang, 1996; Lui, 2003). From the earliest input devices of computers, such as vacuum tubes switch and paper tape, to the modern day keyboard and mouse, computer input devices have always been an important part of CAD systems. No single input device can communicate with computers in a more natural way; users cannot use keyboard to move around on the screen and avoid using mouse. The technology of virtual reality even integrates extensive applications of many hardware facilities with the design and multimedia for Human-Computer Interaction (HCI) (Burdea, 1993; Walter, 1996; Sherman, 2002).

The earliest inspiration for input device is "hand". Engelbart (1968) made public the first mouse in the world, and his inspiration came from using hand movement to control the menu on the computer. However, due to the limit of the monitor, most input devices are designed for 2D interface. Thus, users are confronted with a number of limitations when making 3D design on a 2D interface. Although perspectives and change of viewing angles can be applied to browse the virtual environment, it is still hard to operate the movements on a 2D interface. Thus, the traditional input devices can no longer meet the demands of designers (Tamotsu and Naomasa, 1994; Gross and Kemp, 2001). As a result, intuitive space input devices are introduced, such as “Data Glove”, “Force (space) balls”, “Space Mouse”, “3D Mouse”, which are commonly-used space input devices (Zimmerman et al., 1987; Li et al., 1997; Rosenberg and Slate, 1999; Chung, 2003; Hachet et al., 2003; Chen, 2004).

However, some devices do not require wearing or hand-holding space input equipments, such as laser-based “Touch Screen” (Strickon and Paradiso, 1998), static electricity-based “School of Fish Active Network Sensing System” (Smith et al., 1998). Although “School of Fish Active Network Sensing System” resolves the space movement of 6 degree of freedom (X, Y, Z), it is easily influenced by the distance and substances charged with static electricity in the environment; thus, it is unable to measure the hand movement accurately.

As a result, this research presents an infrared-based space input system, which simulates hand movements and allows designers to control the input of 3D objects by simple and intuitive hand movements. Also, it allows natural operations. Without wearing or hand-holding any equipment, users are able to move freely in 6 degree of freedom (X, Y, Z). The system is called “Hand Movement System (HMS)”, which senses the hand movement in the space, direction and height with the arrayed device of the infrared distance measuring sensor underneath the hand, then transmits the measured parameters to the control system, and converts the data to corresponding coordinates of the virtual space for users to control the 3D objects in the virtual environment.

Literature Review

The design of a user-friendly CAD interface that assists designers in concept designs has been an important subject in the learning of computer-assisted design. Designers first draw a plane framework on 2D software, then constructs a 3D model on a 3D software. This new design concept has thus been derived due to this type of design software, namely “model space” from X-Y plane with Z-axis (Morozumi et al., 2002). The choice of software often affects the result of design. New CAD software continues to integrate visualized graphical interface to the program and improve the algorithm functions of the software. As a result, the development of CAD software is enough to affect the design process and thinking models of the designers. The design changes with the software as well (Serriano, 2003).

Senagala (2003) pointed out that user interface affects the efficiency and willingness of software usage by the designers. He stated that an image in the designers’ mind is a definite and clear 3D image, but the software used by the user presents the image in 2D sketch, and requires him to input on a 2D plane. Serriano (2003) suggested the concept of “Form Follows Software”, and believed that the form is often determined by the design software. Therefore, Tamotsu and Naomasa (1994) proposed the concept of “virtual reality added design (VRAD)”, which helped provide a new method of virtual reality construction to the designers. By using VRAD, the designers can construct and modify the 3D model freely, and view the results immediately to save time and resources spent on constructing the 3D model (Ouyang, 1996).

Since the input interface is based on 3D windows-indicator-menu-point (WIMP) (Gross and Kemp, 2001) to control the 3D object in the virtual environment, there are limitations preventing designers from modifying the design intuitively. Therefore, “hand gestures” and “motions” become the most intuitive input methods. Nemeth (1984) proposed a system framework that uses hand gestures to design in the virtual environment, and compiled a set of hand gesture standards to define the space and form. However, Foley (1987) believed that without a proper training, people have different definitions of hand gestures, and the commonly understood hand gestures are scanty. He

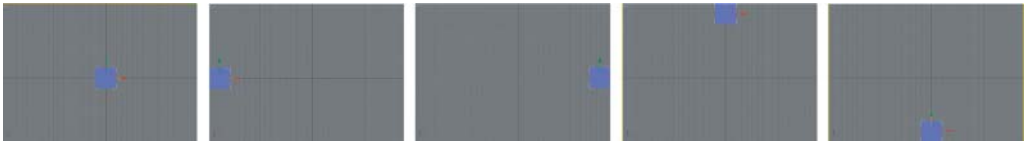

Figure 1. Use 3ds max to create a 3D object in the virtual environment

concluded that hand gestures are unlikely to become a type of common communication method. Liang (1997) also suggested that due to the complexity of the CAD software, there are fewer than 12 natural hand gestures, if no special trainings are provided; thus, they cannot meet the demand of software commands. Joseph and Stuart (1998) proposed that merely learning the operation of the software is difficult enough for users, and it is unlikely for them to learn a set of hand gestures for an input tool.

However, Foley (1987) proposed the concept of "direct operation", which interacts with the computer through direct movements instead of messages or movable messages. Without any special command to modify the message, the objects in the virtual reality can be moved directly as if in the real world. Thus, designers have better interactions with the virtual reality.

Set up intuitional input device: hand mouse system

The methodology comprises three steps:

1. User analysis test and evaluation to analyses the input methods by mouse and hand movement
2. HMS system framework
3. Integration of Hand Mouse System and virtual environment and test evaluation

User analysis test and evaluation to analyze the input methods by mouse and hand movement

a. Analyze the input method by mouse:

This case is intended to test how hand movements operate 3D objects in a virtual environment. First of all, create a 100 cm x 100 cm x 100 cm 3D cube model on 3ds max, and configure the size of the virtual space as 460 cm x 230 cm. Place the 3D cube model at the absolute center of the screen (0, 0, 0) and let the testee to move the cube to the left, right, upper, and bottom margins one after another. (Figure 1, 2)

b. When the testee simulates using the mouse to move the cursor on X-axis to the left, the testee rotates his hand by approximately 45 degrees counterclockwise. When he simulates moving the cursor on X-axis to the right, he rotates his hand by approximately 45 degrees clockwise.When the testee simulates using the mouse to move the cursor on Y-axis to the left, the testee rotates his hand by approximately 30 degrees to face up. When he simulates moving the cursor on Y-axis to the right, he rotates his hand by approximately 30 degrees to face down. (Figure 3)

c. Result of the analyses

Through the analyses of mouse operations, several findings can be deduced as follows:

1. The movements on X-axis of mouse can be operated with the mouse's horizontal movements.
2. The movements on Y-axis of mouse can be

Figure 2. Analyze mouse movement

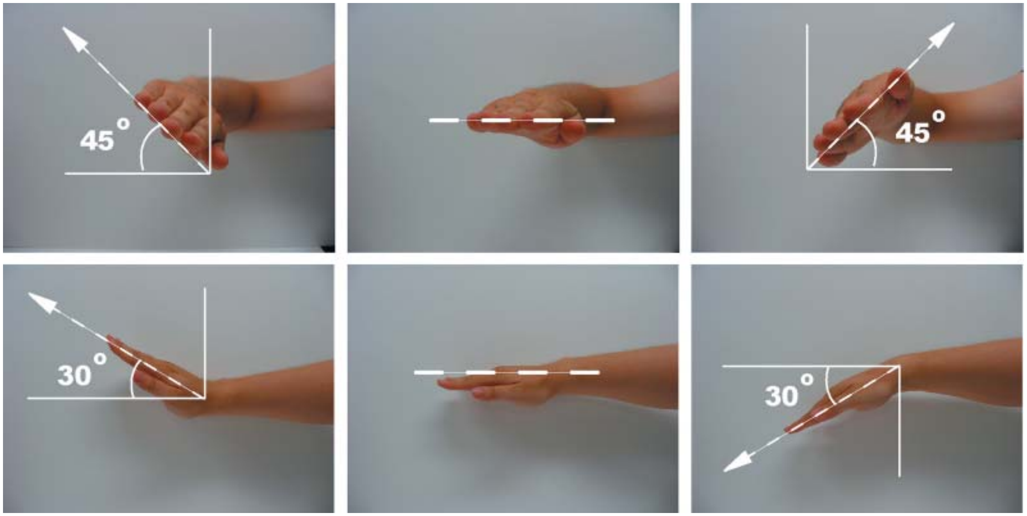

Figure 3. Use hand movement to simulate mouse movement

operated with the mouse's vertical movements.

3. Ordinary mouse, due to the lack of any special configuration or device, do not provide direct operations for Z-axis movements.

4. The rotation of testee's wrist can simulate the mouse's movements on X-axis and Y-axis.

The HMS system framework

a. The HMS operation principle:

The HMS is based on the concept of using rays emitted by infrared sensors to compute the distance between the hand and the device, then using the different spatial position generated by the change of hand movements as the reference for signal input. This study first to set the three hand movements into X, Y, and Z axes (Figure 4), and illuminated the infrared rays on the three positions of the palm, which are A, B and C points (Figure 5). The axial movement of the hand could correspond to the sensory distance of A, B, C points, and convert to displacement distances. Sharp GP2D120 Distance Measuring Sensor was used to obtain the distance data and convert the spatial coordinates system of X, Y, Z in order to manipulate the 3D object in the virtual space.

b. The HMS operating sequence:

This system converts the 3 movements of hand with Sharp GP2D12 into analog voltage signals and transmits them to the computer through RS-232 interface. The signals are compiled and converted again into the x, y, and z coordinates to control the 3D design object in a virtual environment. At last, through visual feedback and hand movements of

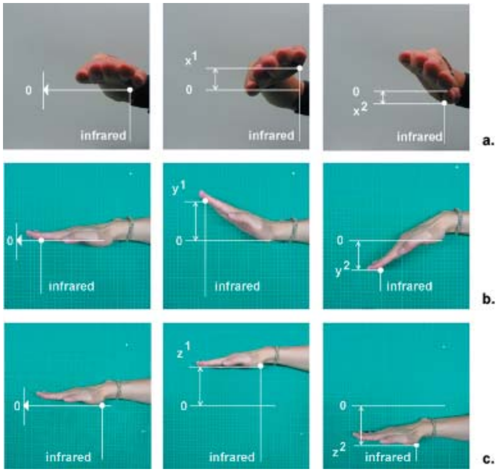

Figure 4. a. Use of arm rotation and palm movement to obtain X axis; b. Use of wrist rotation and palm movement to obtain Y axis; c. Use of palm elevation to obtain Z axis

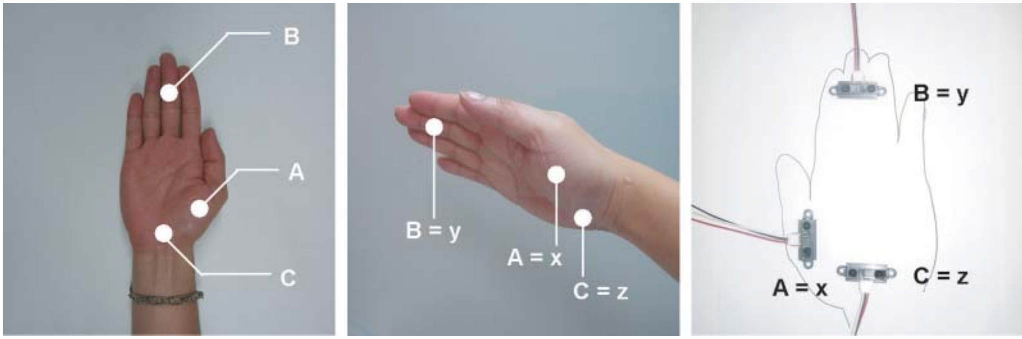

Figure 5. The infrared rays on the three positions of the palm

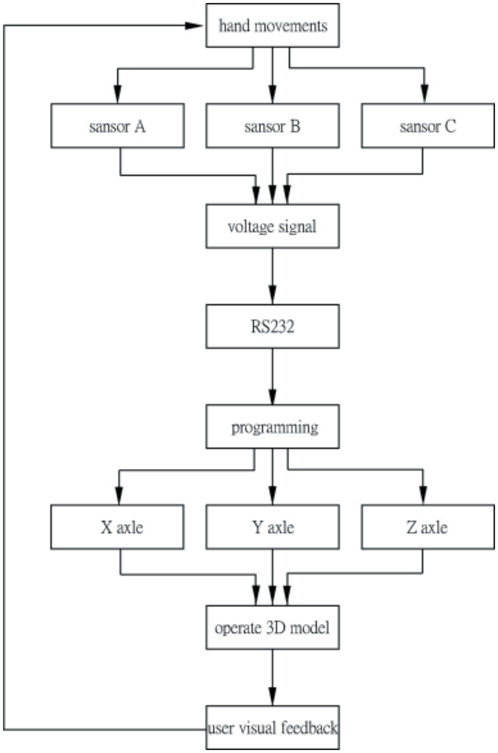

Figure 6. The HMS operating sequence

the user, it can be manipulated intuitively. (Figure 6)

Integration of Hand Mouse System and virtual environment and test evaluation

a. Infrared distance measuring sensor: Sharp GP2D120 Distance Measuring Sensor

The infrared sensor array is mainly composed of 3 Sharp GP2D120 Distance Measuring Sensors, which are responsible for detecting the movement of the 3 control points of A, B, C on the palm, and are connected to the RS232 interface of the computer through iRX.

b. Connecting device: iRX

iRX is an RS232-based connecting device created by Personal Information Architecture of MIT Media Lab. It delivers the analog voltage signal of GP2D120 through RS232 interface to the computer, allowing it to convert the signals into digital signals required by this device.

c. Signals coding

iRX converts the Sharp GP2D120 signals between the voltage of +0.4V ~ +3.1V into figures between 5 ~ 35. A series of strings “a, b, c” (Figure 8) can be derived as the x, y, z on the coordination system.

d. To operate 3D model

The signals compiled by iRX can be introduced to Director 8.5 for 3D model output. First of all, create a 3D design object on 3ds max and save the file in the format of *.W3D. Import this *.W3D file

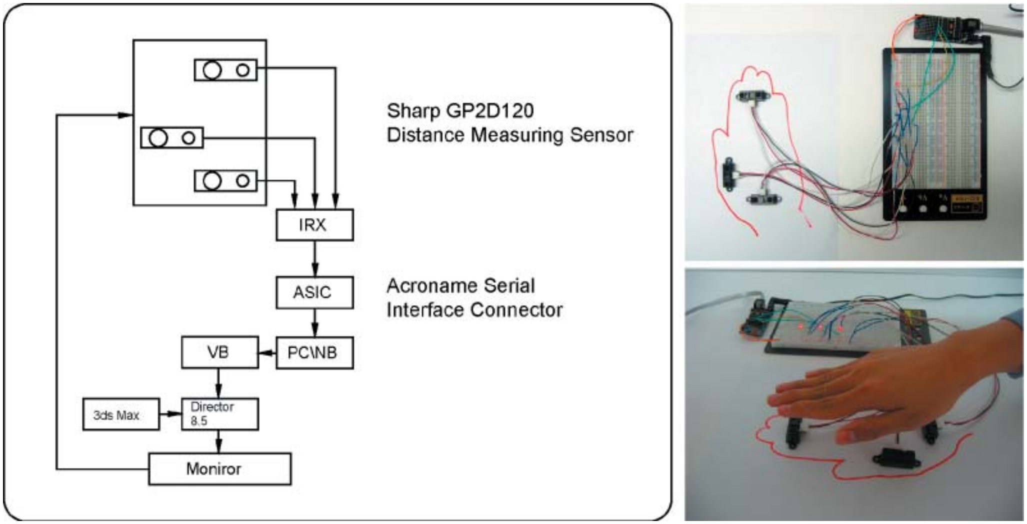

Figure 7. The Hand Mouse System framework

into Director 8.5 and use Lingo Programming Language to edit 3D rotations and movements. Use the digital signals output by iRX as the codes for x, y, and z axes, and set 6 free directions. (Figure 9)

Conclusions

This study provides a simple and economical intuitive hand movement system, enabling users to use intuitive hand movements, without wearing any equipment, to operate 3D objects on x, y, and z axes in a "virtual space" (Morozumi et al., 2002). Different from Data Glove, this device does not require users to wear or hand-hold any equipment, or learn complicated hand gestures. Users can easily operate 3D design objects in a virtual space.

This study is based on the concept of "direct operation" and aimed to provide inputs of different space operations, in hope of integrating other virtual reality technologies, such as VR CAVE, augmented reality, and the Internet as the interface for exploring virtual spaces.

Future works

In the future, the relation between human and the environment will be closer, but should the environment adapt to human beings or vice versa? This has always been a controversial issue. This study thus proposes a concept of "adapting interface to human" in the framework of "the relation of human and interface". Different from the concept of worn or handheld devices, this study attempts to base this application on human's natural movements and make "interface" or "device" feel human's behaviour. Through the interactions between human and environments, natural behaviour are able to operate 3D design objects in a virtual environment and stimulate behaviour of designing in the most natural way.

It can be inferred that countless and various kinds of sensors will be installed in future architectures or environments. With these sensors, a new model of interaction between human and environments will be formed. For long, human-computer interaction (HCI) has been mostly based on human's interactions with computers or focused on

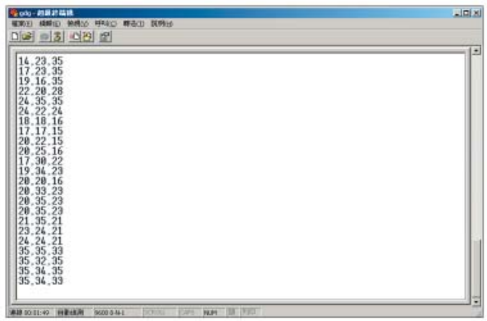

Figure 8. A series of strings "a, b, c" coding by iRX

Figure 9. The HMS can to supply translation and rotation in virtual environment

the interpersonal interactions. But in the near future, human-computer interactions will not merely encompass the interactions between human and machines or environment, and the environments will also be adapted to human's needs. It is the concept of "Smart Architecture". Thus, it is hoped that the study result may be beneficial to the development of human computer interactions in the future.

References

Burdea, G. and Coiffet, P. (ed.): 1993, Virtual Reality Technology, John Wiley & Sons,Inc.

Chen, Y. T.: 2004, Real-time 3D Gesture Interface for Virtual Environments, Master's Thesis, Department of Computer Science, National Tsing Hua University

Chung, G. S.: 2003, Keyboard Input Device Using Data Glove with Tilt Sensors, Master's Thesis, Department of mechanical engineering, National Chung Hsing University

Elsadek, H., Eldeeb, H., Franco De-Flaviis, Jofre, L., Abdallah, E. and Hashish, E.: 2001, Size Reduced Microstrip Planar Antenna Array for a Compact 3D-Mouse Microwave Holographic System, Antennas and Propagation Society International Symposium, 2001, IEEE

Elsadek, H., Eldeeb, H., Horikoshi, J. and Yabe, T.: 1998, New technique for investigating three dimensional (3D) mouse, Systems, Man, and Cybernetics, 1998 IEEE International Conference

Engelbart, D.: 1968, http: //sloan.stanford.edu/MouseSite

Foley, J. D. (ed.): 1987, Interfaces for Advanced Computing, Scientific American, pp.126-135.

Gross, M. D. and Kemp, A. (eds): 2001, Gesture Modeling-Using Video to Capture Freehand Modeling Commands, CAAD Futures, Eindhoven, Netherlands, pp.271-284.

Hachet, M., Guitton, P. and Reuter, P.: 2003, The CAT for efficient 2D and 3D interaction as an alternative to mouse adaptations, Virtual Reality Software and Technology, Proceedings of the ACM symposium on Virtual reality software and technology, Osaka, Japan

Joseph, G. and Stuart, K. (eds.): 1998, Three dimensional software modeling, Proceedings of the 20th international conference on Software engineering, IEEE Computer Society, Kyoto, Japan, pp.105-114.

Li, S., Hsu, W. and Pung, H. K.: 1997, Twins: A Practical Vision-based 3D Mouse, Real-Time Imaging

Vol: 4, Issue: 6, December, 1998 pp. 389-401.
Liang, J. H.: 1997, A Real-time Continuous Gesture Recognition System for Taiwanese Sign Language, Institute of Information & Computing Machinery, Taipei, ROC.
Lui, Y. T.: 2003, Developing Digital Architecture 2002 FEIDAD Award, The Birkhauser Press.
Morozumi, M., Shimokawa, Y. and Homma, R.: 2002, Schematic design system for flexible and multi-aspect design thinking, Automation in Construction 11 2002 147–159
Nemeth, C.: 1984, Maestro: A Gesture Recognition System, Institute of design, Chicago, Illinois, United States.
Ouyang, M.: 1996, The Technical Nucleus and Future Develop of Virtual reality, Institute of Information & Computing Machinery, Taipei, ROC
Rosenberg, R and Slate, M.: 1999, The Chording Glove: A Glove-Based Text Input Device, IEEE Trans actions On Systems, Vol. 29, No.2, pp.186-191.
Rowe, P. G. (ed.): 1987, Design Thanking, The MIT Press.
Senagala, M.: 2003, Postspatial Architectures: The Emergence of Time-like Parametric Worlds, paper published in Cultura Digital y Diferenciacion, Proceedings of the SIGRADI International Conference, Rosario, Argentina, pp. 375-382. ISBN: 987-9459-51-2.
Serriano, P.. 2003, Form Follows Software, ACADIA 2003, pp.185-205
Sherman, W. R and Craig, A. B.: 2002, Understanding Virtual Reality: Interface, Application, and Design, Morgan Kaufmann Publishers
Smith, J. R., White, T., Dodge, C., Allport, D., Paradiso, D. and Gershenfeld, N. (eds.): 1998, Electric Field Sensing for Graphical Interfaces, Computer Graphics and Applications, Vol. 18, No. 3, 1998, pp 54-61
Strickon, J. and Paradiso, J.: 1998, Tracking Hands Above Large Interactive Surfaces with a Low-Cost Scanning Laser Rangefinder, In CHI98; Extended Abstracts, ACM Press, NY, April 1998, pp. 231-232.
Tamotsu, M. and Naomasa, N.: 1994, Direct and intuitive input device for 3-D shape deformation, Proceedings of the SIGCHI conference on Human factors in computing system: celebrating interdependence, ACM press, Boston, Massachusetts, United States, pp.465-470.
Walter, J. G., 1996, “Developing the Tools for Practical VR Applications”,
IEEE Engineering In Medicine and Biology, March/April, pp.23-30.
Zimmerman, T. G., Lanier, J., Blanchard, C., Bryson, S., & Harvill, Y. (eds.): 1987, A hand gesture interface device, Proceedings of the CHI+GI ‘87 Conference on Human Factors in Computing Systems, 189-192. New York: ACM.