Space Cube: A 3D Puzzle for Study Model

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Abstract: In the process of architecture design, the manufacture of study model acts a procedure of swift transformation from concept to a visible model. Since the era of CAD/CAM approaches, the tool of constructing the model evolves from the traditional physical model to digital model in the mode of the manufacture of study model. The virtual model, which is utilized in the incipient concept discussion by the designer, has become a new intermediary material. However, the virtual model or physical model respectively acts its role that may not be substituted now. TUIS (Tangible User Interfaces) is the intuitional interface system of discussion on striding these two intermediary materials. By the information interchange between the physical model and virtual model, a designer can dedicate to the procedure of design development rather than be restricted to the operation and usage of these interfaces. However, there are many problems existing in applying such a system to the solid geometry model stack. This essay will discuss that a designer explores the incipient design application by manipulating physical model and virtual model.

1. INTRODUCTION

In the procedure of concept design, solid geometry models stack is used frequently and the relationship between the space and proportion can be realized rapidly through it. For example, Frank O. Gehry usually uses lots of study models to ponder the relation between shapes. The intermediary materials commonly used at present may be divided into the physical model as well as virtual model. The physical model occupies the substantial space and provides manipulator the existence and intuitional operation (Cheng 1995). However, there are drawbacks existing in these repeating operations.

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Not only time is wasted in the stage of concept development but also information drains away because of repeating redrawing to modification in the stage of concept development. The digitalization of these incipient concepts will be favorable to the design development (Herbert 1993).

At present there are many software tools for digital modeling which can draw the digital model swiftly. The digital model provides better reality simulation and freedom of modification and supplies some computer characteristics that are different from the physical models to assist the designer: the characteristics of duplication on computer, the speedy construction of model, the easier modification, the analogy of material quality, and assigning different physical attributes to the virtual model. Nevertheless, the virtual model is devoid of the real tactus and the performance of overall feeling for controlling the model (Chang, 2005). Because they were not familiar with the computer interface or the procedure of operating the computer in the past, many designers have difficulties in the manipulation of new intermediary materials or cause the difference between the essence of design and original idea during the operations.

Furthermore, some researchers make a comparison between the physical and digital models for this issue (Lin, 1999). The combination of digital model and virtual reality make the model more stereoscopic or the usage of data-glove and force feedback glove increases the tactile sense of reality of the virtual model (Regenbrecht et al., 1993; Wu, 2003). Except for the virtues of digital model, these researchers hope to find the essence deficient in the digital model or that cannot be substituted in the physical model.

In the procedure of incipient manipulation, the designer usually uses both physical model and digital model but both are utilized separately in general. The mutual influence was exerted by no means because of different attributes between them. The physical model can supply the intuitional thinking mode of design but there is deficiency of ability of immediate modification. However, despite the provision of analyzability and analogue in digital model, it usually is a mere presentation of formality in the last stage of design (Conti et al. 2000).

Recently there are some research reports that utilize solid geometry models as the basic physical model. When a designer uses the unit motion, virtual solid geometry models starts an immediate synchronized movement (Murakami et al. 1994; Gorbet 1998; Lee 2003; Eng et al. 2004). But there is deficiency of information of virtual feedback in this mode. There are other researches published that the model is connected to the computer and the shape constituting of these cubes can be discerned by the computer after the designer installs the models (Anderson et al. 2000; Sharlin et al. 2003). However, the procedure of discerning solid models installation is not real-time either connection with the computer or disconnection and the user

cannot interact immediately with 3D models while constructing the cubes. Since the connection of cube is through the unidirectional joints, the directionality of cube connection is restricted.

Based on this essay, the spatial cubes can be created for the interaction between physical and virtual that even more intuitionally controls the physical model corresponding to the position in the virtual three-dimensional space. By the information coming from the virtual circumstance, the researcher can proceed the next step of solid geometry models manipulation, explore how to integrate both characteristics, and apply it to the stake process of solid geometry models in the incipient design.

2. RELATED WORK

In most of the systems constructing the 3D model, input system primarily by instructions or Graphical User Interfaces (GUIS) is still the most efficient input implement for the 3D model. The keyboard and mouse are still indispensable for a user to choose the instructions. Because these instructions are complicated and abstract concepts for a user, the user has to ponder these complicated motions then to scrutinize and correct the 3D model. Therefore, the user might be restricted in such intermediary materials to ignore the original idea and transfers to the miscellaneous operation process.

Designing Tangible User Interfaces is a new concept about the design interface. This is an interface connecting the physical interface and virtual information. It is more intuitional than the traditional GUIS interface. The design procedure will be more simplified by the computer interface of TUIS process and the designer can intuitionally operate the intermediary materials on the computer to support the proceeding of design. TUIS technology is a new intermediary material of digital design in the procedure of design. It supplies some new auxiliary functions for the design and allows the designer to be easier to operate the virtual digital media or to get more auxiliary information for recovering the insufficiency of physical model. Therefore, the new intermediary material for digital design, TUIS, changes the roles of virtual and physical models in the design process. At present we can realize from some examples how the physical model coordinates with virtual model by TUIS to provide remarkable potential and influence in design process.

Digitizing Stacked cube models is a simple method to help designers understand and analyze the space constructions and system frameworks (Aish 1984). Besides, several relative researches have showed that interfaces such as Machine-Readable Models fit intuition quite well (Frazer 1982). Recently, certain researches even developed into a further step. By using

solid geometry models connected with computer, the virtual models react simultaneously while designers make digitized units moved (Murakami et al. 1994; Gorbet 1998; Lee 2003; Eng et al. 2004). However, this kind of operation mode lacks reality feedbacks from virtual systems. Some other digital model researches adopted a different kind of mode. By using electric-connected units, models of these units could link up with computers and be identified (Anderson et al. 2000; Sharlin et al. 2003). Nevertheless, this kind of process is not real time reacting no matter connected or not. During the unit-contracture process, the user cannot interact with the 3D model in real time. Moreover, since units are connected with the single phase connector, the connected phase is also limited somehow.

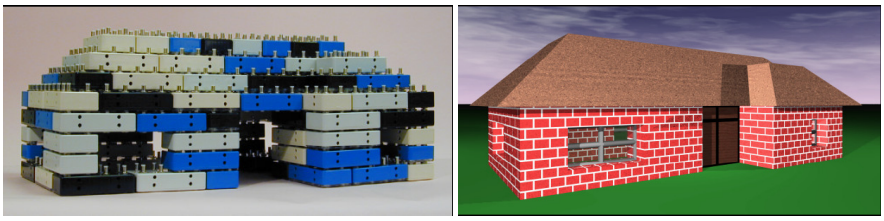

Figure 1.

The simulation of cubes displays not only the simulation of shape in the virtual circumstance but also the control of virtual model in some related researches by dynamic methods. By the manipulation of hand to change the shape of physical model, the virtual model simultaneously produces real-time change of shape.

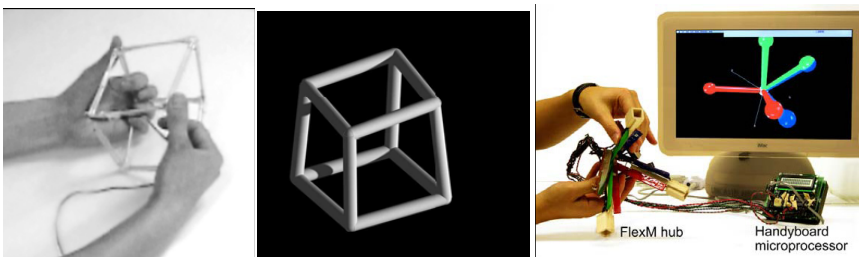

Figure 2.

3. INTERACTIVE TECHNIQUE

Due to the limitation mentioned above, a new method is developed to solve these issues. By using a real time interaction implement, solid geometry models could control the virtual ones on the screen. In the meantime, virtual model could also give feedbacks simultaneously for interaction. Below is the process in detail:

(1) When a designer picks up a physical cube, this cube can be mirrored on the computer screen with a digital cube. No matter which cube moves, the other one will acts as another in motion and position.

(2) While the designer is stacking physical cubes, virtual ones are also stacked simultaneously on the screen.

(3) The designer can check the virtual cubes for further information, such as scale, position, and volume...etc

(4) According to information above, the designer is able to adjust physical cubes to fit his formulation.

(5) During the adjustment, virtual cubes picked up on the screen will synchronize the physical ones to light up. This expression can let the designer to check if his strategy fits the stacking model or not.

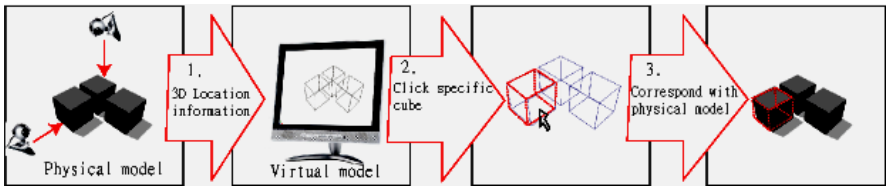

Figure 3.

3.1 Realistic interaction

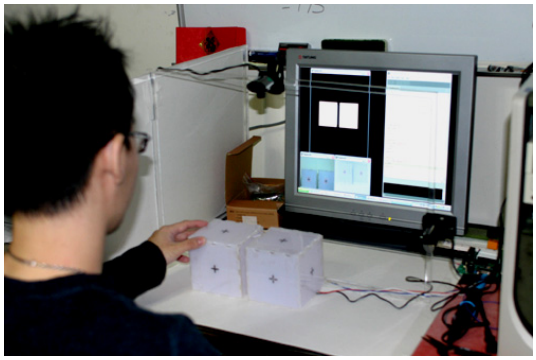

Figure 4.

1. Physical model position detecting
The instinct of physical cube stacked is by using programming language "wiring" method to analyze the webcam image, arranging two group of web-cam to track the physical model in the X, Y and Z position. By this kind of 3D positioning method, it can precede the physical and virtual model at the same time to interact the cube stacked game.

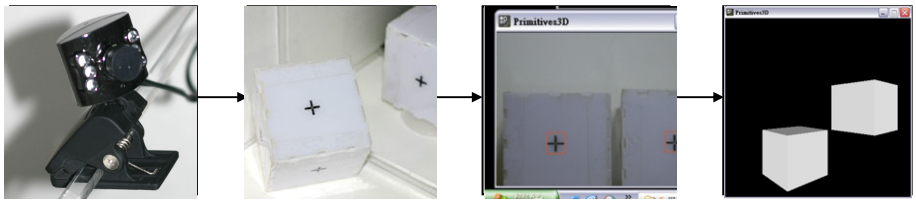

Figure 5.

2. Analyze Virtual Model.
According to the above procedure, virtual model base on the physical model can provide different analyze information. Like 3D position, percentage and quantity, base on these information, to choose specific cube, it can be exam individually.
3. Message Feedback Device
According to the procedure mention above, the procedure will finish specific virtual measurement in response to the feedback of real measurement; using the technology of touchable design of Designing Tangible User Interfaces, it

will receive the feedback measurement message. At the same time of pointing to the specific virtual model, the position of same 3D measurement model will corresponding to it. When both correspond, the light of physical measurement will let designer aware.

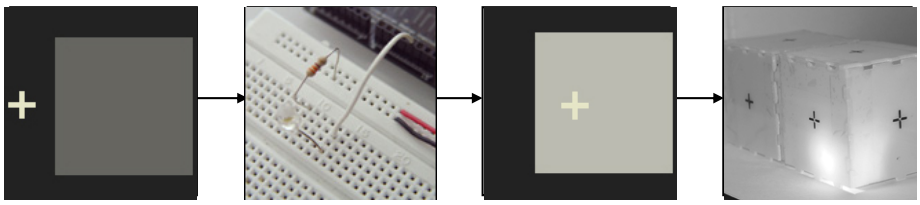

Figure 6.

3.2 Play and build

The purpose of this experiment is to provide a platform for the designers to play and build the 3D model. It can help them to develop the concept and alleviate the burden of designers at the complicated interface of constructing model. Because to build the 3D shape needs the imagination and execution, it is necessary to deliberate the procedure rather than the shape itself. There are a series of transformation of thinking modes existing in making the design target and forging the 3D model. This procedure of transformation is trivial and incomplete and there is little direct connection with design process. After the designer designs the shape, his work will transfer to the mode of constructing model. Apparently design and shape-input by complicated instructions are totally different two things.

4. IMPLEMENTATION

Space-Cube is a physical interface that the 3D information can be inputted and it can execute the operation of virtual model system. The hardware of Space-Cube consists of physical materials, I/O board, electric circuit boards, and LEDs. The virtual model can make Space-Cube transfer to outer input device by the application of Wiring.

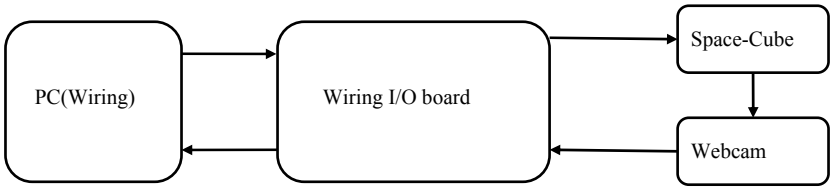

Figure 7.

4.1 Physical interface

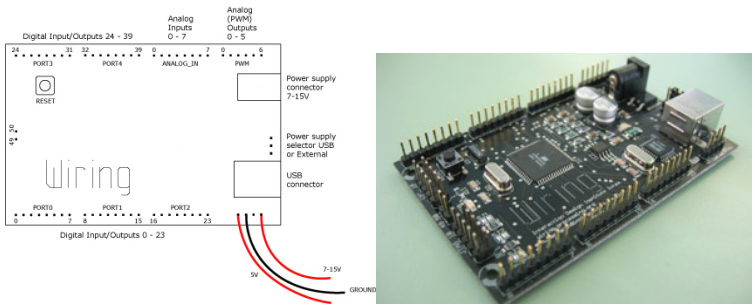

Figure 8.

Space-Cube, fabricated by laser cutting, is a cube consisting of acrylics. The cube is connected to computer by means of Wiring I/O board, which is a small circuit board including a stamp-size microcontroller, and Wiring I/O board directly connects to the computer through USB cable. After it identifies Wiring I/O board, the computer can directly read and transmit data. The computer can control the sensors and actuators under the Wiring circumstances and collect the necessary information such as temperature, light, and distance from the sensors. The actuators can exercise the realistic motions by the control of circuit such as LEDs and electrical motors. A circuit board is installed inside the cube to control the LEDs and LEDs accept the signals of Wiring programming language to control on-and-off.

4.2 Software

Wiring is a programming language that is established under the structure of Processing. Basically, Processing is a circumstance of programming language that the designer, who may be a student, an artist, or an architect, can uses it to compile image, animation, and voice. It is created to be a programming language based on the image. Wiring, which is different from

Processing, is a circumstance combining electrical circuit board with programming language to explore the electronic art and tangible media. A user utilizes Wiring to teach and learn the computer program and the prototype. Wiring defines a fact: to control the electronic devices and hardware by programming language can be finished through the exploration of physical interaction design and tangible media.

5. EXPERIMENT

This experiment provides a method to test their adaptation degree of an expert and a novice for using the different 3D input implements. The definition for an expert is a user who is familiar with the traditional 3D interface but a novice is not. An assumption in this experiment is that an expert whose performance is better than a novice in the traditional interface does not definitely have more knowledge than a novice because his familiarity with those different instructions helps him to approach the target. If the more efficient intuitional Space-Cube compensates the gap between an operator and a computer, a novice's performance will compete with an expert.

5.1 Experiment set-up

A 3D modeling circumstance is installed in a desktop. There are a PC, a 17-inch screen, Wiring software, Wiring I/O board, mouse, keyboard, and Space-Cube. A user uses the desktop to manipulate the mass model. When the physical cubes are beginning to stack, the virtual cubes will appear on the screen. A user can scrutinize the information transmitting between the physical and virtual cubes to arrange the physical model.

5.1.1 Experimental condition

An assumption is set in this experiment that the expert and novice have to create his physical model and a synchronous virtual model on the same interface. Meanwhile, these two models must fit the amounts and shape required in this experiment. Then the time they spend need to be recorded. It means that Space-Cube can achieve an intuitional 3D manipulation and decrease the time of learning 3D interface if the consuming time for both is equal.

The usage of mouse is not restricted in the experiment because an expert will follow his familiar ways to operate when he manipulate some simple actions such as movement or click. It suggests that an expert operates

according to their ordinary procedure then to analyze the difference between an expert and a novice.

5.1.2 Experimental task

The experiment is divided into three stages and each stage is a procedure of representation building of model. The first stage is that a user has to stack three masses and the virtual model is present. The second stage is to stack a pyramid. The third stage is that a user stacks any shape he wishes during ten minutes.

5.1.3 Experimental design

The testees are divided into two groups in the experiment by their familiarity with the 3D modeling. One is the members of experts and another is the members of novices. They all use Space-Cube as the input implement. In the beginning of experiment, they are allowed to explore this circumstance in ten minutes then to manipulate three stages of experiment.

5.2 Experimental results and discussion

There are four volunteers participating the experiment. Two of them are familiar with the 3D modeling and the other two are not. They, whose age is among 25 to 30, all have the background of design.

5.2.1 Analysis of overall results

The experiment will be recorded on a videotape to analyze the consuming time and procedure. Generally, the users should spend much time to ponder how to operate their expected shapes. The next is the procedure of manipulation. For the experts, they spend much time on observing how to operate the instructions of computer interface so the whole procedure will be more trivial because the recurring operations in the procedure result in repetition. For the novices, different from the experts, they concentrate on physical cubes. They first take notice of the method of using physical cubes rather than the virtual interface. Except for difficulties occurring in the operation, they don't manipulate the virtual interface and instructions. However, it takes more time in the process of groping the virtual interface. Generally, the person using Space-Cube will easily concentrate on the physical model itself to facilitate the complicated instructions. Because there are virtual and physical interfaces simultaneously existing, testes with

different backgrounds will focus on different parts but the consuming time for both groups is similar.

6. DISCUSSION

Making the study model by hands is an intuitional interaction way that the designer's concept can be concretized. The purpose of using Space-Cube is to reduce the complication of thinking when a designer is drawing the 3D mass. This experiment proves that the application of Space-Cube can simplify the procedure of making 3D mass. During the procedure of design, a designer should have more space to image and evaluate these shapes and not be disrupted by many complicated operations. The essay represents that a 3D input implement based on the physical model has the ability of interaction with human hands and also enhances the intuition of 3D modeling.

This system may facilitate the complexities of user interface by analyzing the information at manipulating this implement. A user can concentrate on the cubes on his hand and the idea rather than instructions and menu. Space-Cube can transfer 3D model design from the abstract instructions to human-hand operation mode that promotes the intuition of 3D modeling. However, the main disadvantage of this implement is the lack of precision for detail revise. It is not suitable to install any sensor on this implement because it is complex to select and arrange these specific sensors on each of the six surfaces. Meanwhile, a transformation mechanism should be created for the different occasion.

Some operators begin to comment that Space-Cube is such a specific mechanism with particular modeling mode and not so universal like mouse and keyboard. However, the general modeling interface is usually designed for the common input implement. Although the mouse and keyboard are convenient tools for mode switch, it is unfair to evaluate them from this point of view.

From impression, it is a restricted method to use Space-Cube to manufacture the model because the user only interacts with this implement by hands. However, it can quickly assist the user to solve the specific procedure. On the other hand, there is much freedom to exercise the task by using the mouse and keyboard but it wastes much time because of redundant instructions. Because both tools provide partial requirement for the 3D modeling, in the next step, these two concepts of design can be combined. In the future research, it is expected that the mass stack can coordinate different instructions to virtualize the more exquisite virtual model through the combination of these two intermediary materials. For example, a basic mass

of car is stacked first and the instructions can simulate its precise details and materials in the virtual model. By this method, it can help a designer to scrutinize what the incipient design procedure influences the later stage of design.

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