

## CONCEPTUAL MODELING ENVIRONMENT (COMOEN)

*A 3D user interface for integrating the use of tangible tools into conceptual modeling*

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**Abstract.** Conceptual modeling is an actively creative stage in a design process. Through hand modeling and manipulation of different kinds of modeling tool kits for specific materials, designers are able to generate forms. This article presents a tangible human-computer interface of a C-StressBall for form manipulation and a C-BenchWhirler for visual control. They create a new way of interaction between the virtual world and the physical space. They are aimed to ease the operation in design process by using CAD.

### 1. Introduction

#### 1.1. CONCEPTUAL MODELING IN ARCHITECTURE DESIGN

The concept in the early phase of architecture design is considered as the key direction force of design creativity (Huang and Liu 2001). Designers can think over detail design of forms by manipulating models in the real world and switch the perspectives of designed forms freely (Lee 2002). While developing concepts, designers usually generate different aspects of visualized thinking by creating conceptual models (Goldschmidt 1994; Liu 1996; Schön and Wiggins 1992; Suwa et al. 2001). Tangible operations of hand gestures help in design thinking of solid models. In traditional design process, clay, foam and paperboard are generally used in creating conceptual models.

Tangible sense is a communication tool. It is helpful to enhance hand gesture and express more creative ideas by the senses of solidness by touching the material and transforming the spatial ideas into design models (Bolt and Herranz, 1992; Sturman and Zeltzer 1993; Hinckley et al. 1999). Nowadays, although a CAD (Computer-Aided Design) system is deeply

involved in the design process, a designer still needs to adapt to the CAD system. One of the major obstacles is the lack of tangible operations.

## 1.2. USING CAD IN CONCEPTUAL MODELING

Using physical materials, a designer can handle direct carving, piling and modeling, and forms can be developed easily. However, manipulating objects in real world is limited by physical dynamics. Therefore, it is hard to generate free form with a high degree of freedom. While fabricating free forms, a designer has to overcome material constraints, fabrication difficulty, and time-consuming labor efforts of cutting and gluing. Fortunately, existing CAD systems (such as Maya and Max) contain diverse functions and high capacity of computing power. It becomes easier to overcome the traditional limitation of free form development (Lin 2000). Furthermore, it becomes possible to have a way to create form more freely in the virtual environment.

Although a CAD system provides advantages in versatile functionalities, it causes alienation in the design behaviors of designers during the design process (Won 1999; Wong 2000; Brady 2003). The operation of the GUI (Graphical User Interface) goes through mouse and keyboard. The situation causes difficulty in adapting to the new system while lacking the sense of real space (Lee et al. 2003). Rather trivial efforts with real materials need to be extracted into long steps in CAD system. Extra cognitive load leads to the gap of design thinking and command manipulation. It indeed takes extra effort in planning rather than form generation (Figure 1).

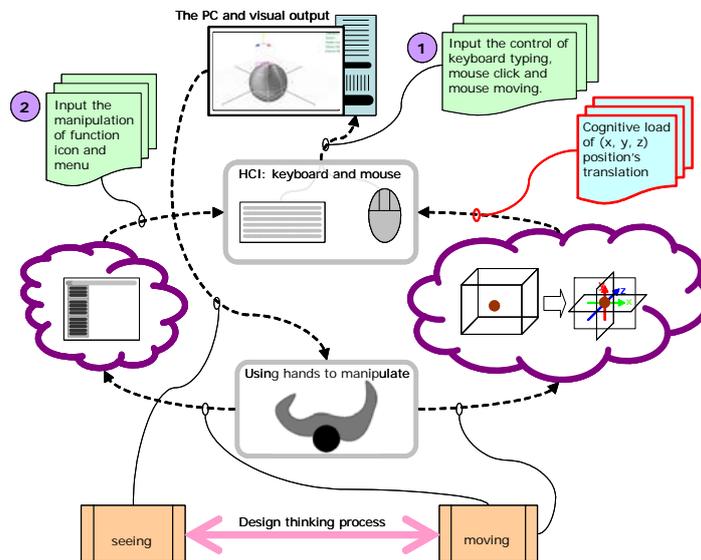


Figure 1. Cognitive loads in design process

The coordination of input/output devices as the medium constructs the framework of human and information (Hsu 1993; Trewin et al. 1999). However, the existing pattern of human-computer interaction does not satisfy our direct form manipulation (Foley 1987). As a result, a designer cannot really lay focus on the design issues.

### 1.3. GOAL OF THE DESIGN

Some researchers have pointed out that the traditional GUI interaction cannot satisfy the needs of a designer anymore, especially in the early phase of the design process (Gross and Kemp 2001; Tamotsu and Naomasa 1994). CAD needs to have a new solution for resolving the limitation of graphical user interface. In 1991, Mark Weiser (1991) published an article on his vision of Ubiquitous Computing, illustrating a different paradigm of computing and HCI (Human Computer Interaction) which pushes computers into the background and leaves only the valuable information directed to the users. In 1997, Ishii (1997) proposes tangible bits which bridge the gap between cyberspace and the physical environments. Tangible media provide meanings to practical usage through input/output interface. They create a new way of interaction between the virtual world and the physical space.

This research points out some deficiencies with the current CAD systems and proposes a resolution of interaction model which fits with the original behaviors of design practices. The aim of the research is to target the following points: 1) Redesign a CAD system that fits in with the early phase of design process; 2) Use TUI (Tangible User Interface) to replace current GUI which is hard to operate in terms of HCI; 3) Construct a working prototype which is suitable for a design environment. C-StressBall and C-BenchWhirler are introduced here as two new tangible interface. They are aimed to ease the operation in design process.

## 2. Approach

Compared to the traditional physical modeling tools, mouse and keyboard of the current CAD system are difficult for design use, even though the digital tools have brought up many potentialities. The traditional modeling tools are actually very complete such as pottery tool kits, ribbon tools, box wood modeling tools, and so on (Figure 2). Moreover they assist in visual thinking by coordinating with the position of the benchwhirler. These traditional modeling tools have existed through human civilization and evolved for a long time to develop the detailed functions in the model-shaping process. And, these tools have a unique characteristic: the users could understand their characteristic easily through the sense of touch. By different strength and angles, a user can learn how to use them correctly. After studying for a short time, people may get used to them and directly create their work.



Figure 2. Traditional physical modeling tools

These kinds of ease in usage and exquisite manipulation are not provided in GUI. On the contrary, they are the features of tangible objects. Therefore, how to design the operation of the tangible objects, and how to establish contact with the tangible's features and the modeling behaviors in virtual environment are our research focuses. In this article, we present two physical tangible tools: C-StressBall and C-BenchWhirler combined with the COMOEN (COnceptual MOdeling ENvironment). Together, they offer a set of new methods of modeling.

### 2.1. REALISTIC INTERACTION

The concepts of C-StressBall and C-BenchWhirler come from the traditional modeling tool kits and C-BenchWhirler. We are providing the exquisite sense of touches by hand during the process of modeling. C-BenchWhirler is a circular turntable to make fast and easy adjustments. C-BenchWhirler provides a way of revolving the turntable with the hand, which will rotate the objects in the virtual environment (Figure 3A). As the turntable is rotated, it places objects on the C-BenchWhirler along with rotation.

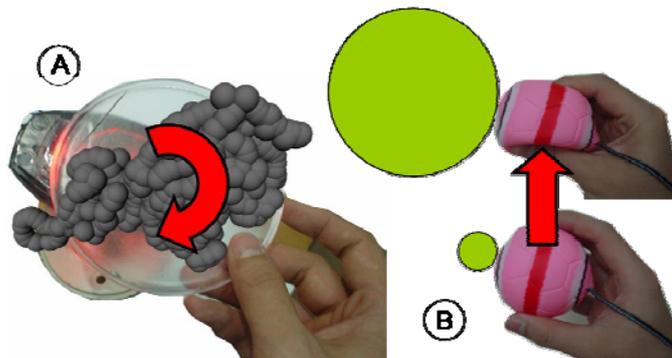


Figure 3. Interaction of tangible tools. (A) C-BenchWhirler provides the function of rotating a virtual object; (B) Through the extrusion of hands, C-StressBall provides the function of creating solid ink.

C-StressBall supplies a surface of sphere for designers to hold with the fingers and extrude the substances for design. C-StressBall is like a container

which is full of jelly ink. Squeezing the C-StressBall would make the virtual objects come out. C-StressBall responds to the squeeze pressure by creating different sizes of ink dots (Figure 3B). Following gesture activities, C-StressBall makes models in any location of COMOEN.

## 2.2. SCENARIO

Here, we have the following scenario planned:

The designer takes C-StressBall and moves in the space. At the same time, C-StressBall follows the movement on the screen in front of the desk. Just like a mirror, it reflects movements directly. On the screen, the spheroid changes according to the hand pressure, like the actual feeling from which the objects crowd out from hands. So, the designer can create three-dimensional forms in the space according to feeling, and organize his design inspiration. On the tabletop, there placed C-BenchWhirler. The designer occasionally rotates the turntable, and the virtual objects moved along with the rotation of turntable. The designer investigates the forms with different angles while rotating the C-BenchWhirler. And C-StressBall is still used in consolidating the ideas at the same time.

In the process, the designer does not realize he is using CAD, but he knows it is an intuitive modeling environment. We put forward the concept of a tangible tool via a CAD system, and offer users to operate CAD information from the tangible tools. The designer can obtain a higher level of satisfaction out of the design process of COMOEN.

## 3. Implementation

### 3.1. SYSTEM OUTLINE

In software, we utilize MEL (Maya Embedded Language) to program new functions as plug-ins for the Maya 3D environment. In terms of hardware, Matrox CronosPlus image capture board is used for retrieving computer vision data from two CCD cameras, in order to obtain the actual spatial position. The functions of optics inductor from mouse and the infrared ray receiver from IRX board offer the sense of touch operation. Through the serial port, the sensed data are sent to the computer. In terms of CAD system, we use the 3D virtual environment in Maya. In COMOEN, tangible tools include C-StressBall and C-BenchWhirler on the table. And the 3D image is projected in front the table (Figure 4).

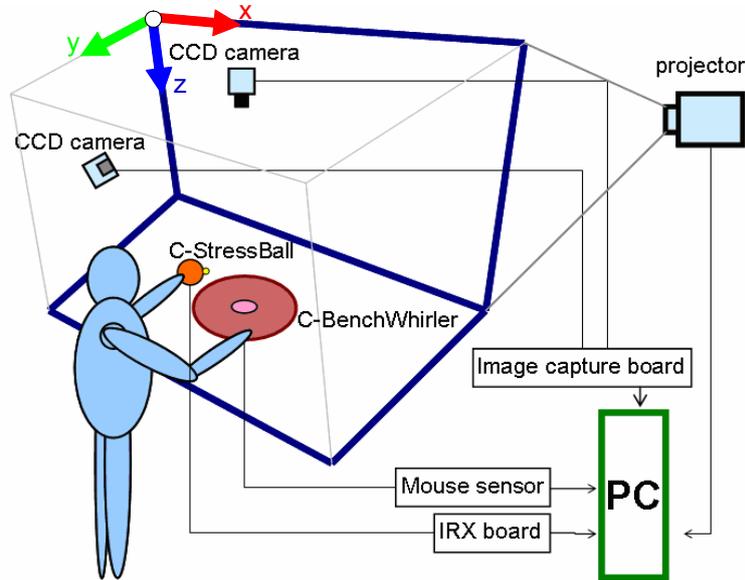


Figure 4. Framework of COMOEN

### 3.2. INPUT AND OUTPUT SETUP

#### 3.2.1. Input of Tangible Tools

C-StressBall is made from a hollow plastic ball. The C-StressBall can be easily caught and pinched by hands. After pinching the ball, C-StressBall can resume its original figure in real-time. The ball is equipped with an Infrared (IR) Distance Sensor inside. When pressing the ball, the IR Distance Sensor can capture the pressure level from the distance of the interior surfaces. Greater pressure creates a larger spheroid. The other way round, minor pressure creates a smaller spheroid. With this principle, C-StressBall can create the spheroid of different size.

In order to get the information of spatial position one CCD camera is placed on the  $(x, y)$  plane and the other on  $(y, z)$  plane separately. Through connecting CronsPlus board and using MIL (Matrox Image Library), the system detects the images derived from both cameras under Visual Studio operational environment. The LED light is recognized and points out coordinates (Figure 5) based on an illumination value. Hence, we can obtain the position of C-StressBall in the space.

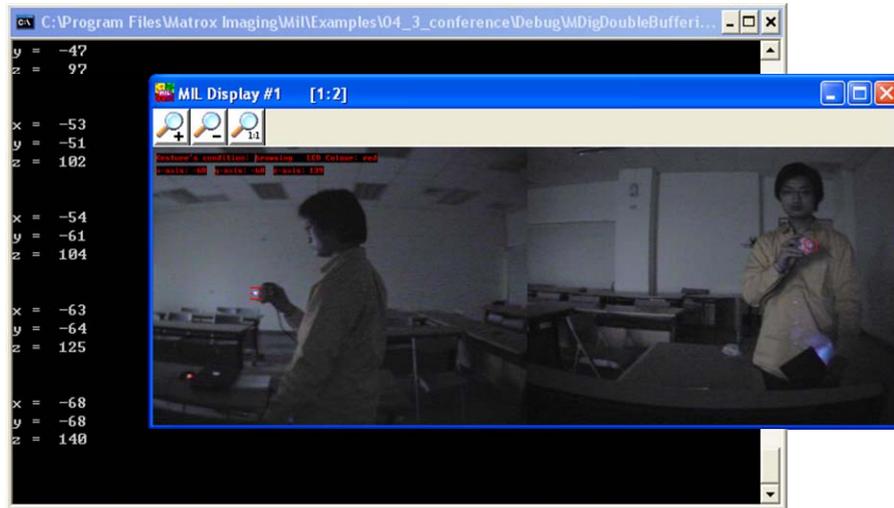


Figure 5. Spatial input interface

C-BenchWhirler offers a round rotary table on the desk, and an IR sensor under the table to detect turning actions. IR sensors detect the directions and the distance when C-BenchWhirler rotates. The edge that catches the rotary table through hand can rotate all objects in virtual environment.

### 3.2.2. Output of the Virtual Environment

In Maya environment, the mouse has been repackaged into C-BenchWhirler and uses the rotation function in the existing Maya software. In order to obtain the spatial coordinate information, we use the image based spatial input interface to obtain the position information. A txt file format is used save the information of (x, y, z) position and pressure strength from the IRX board (Figure 6). The C language is used to program new functions in Maya so that Maya can use the information in virtual 3D environment from the txt file (Figure 6).

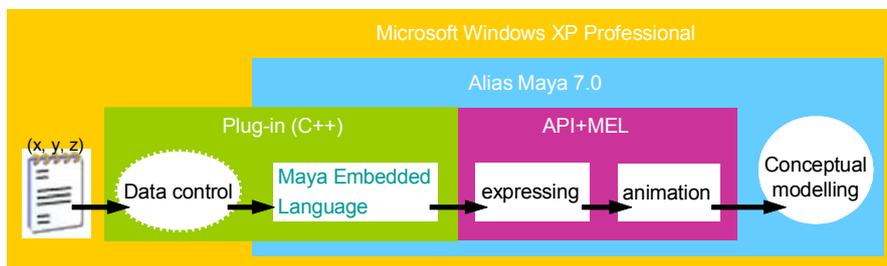


Figure 6. Software Architecture

In Maya, we use MEL to create a new function, which is to get the information of position and pressure level from C-StressBall. That new function makes modeling activities work. In the program, it reads the value of (x, y, z) position and radius from txt file. Then, use the received values in sphere command and execute command in Maya. We named these process “post1”. For real time animation, “post1”command set to immediate execution. Finally, COMOEN can translate the operation of tangible tools into modeling commands.

#### **4. Discussion**

##### 4.1. CURRENT OPERATION PROBLEMS IN EXISTING CAD SYSTEM

The personal computer provides the possibility for users in creating, editing and saving complicated data structure. These functionalities extend the field of human’s imagination which might overcome the constraints of gravity and enhance design thinking in various from development.

3D modeling system based on parameter controls is difficult to integrate digital data and design thinking. The traditional method starts with drafting in pen and paper. And then the drafts would be developed and converted into 3D models. However, the detailed information such as design instincts and art expression could be lost during conversion.

In our example project, we address the contextual environments. The user activities in the physical world could be captured into spatial coordinates and represented with vertex and line extrusion in digital world.

Precision of size is the not key point of 3D modeling. The point is to provide an easy and efficient way to define the clear relationship in the locations of objects. The relationship is in fact the focus of communication between physical and virtual space. TUI has more direct manipulation of objects rather than GUI. Our goal is to identify a better way to establish the link between the tangible and the virtual.

##### 4.2. NEEDS OF DESIGNERS IN THE EARLY PHASE OF DESIGN PROCESS

The Teddy project provides a way to create 3D objects directly with 2D drafting interface (Igarashi 1999). It simply uses lines as the basic design tools to create 3D mesh surfaces. Users do not need to use vertex control to accomplish complicated editing operation. The system indeed provides an easy and smooth way in the specific design phase. However, it is limited to constructing simple toys with round objects. Compared to our modeling environment, we provide more opportunities of the creativity in terms of spatial perspectives. Our system will be more helpful for architects to obtain a better sense of space.

In a traditional CAD system, it is insufficient for designers to fully bring creativity. Surface drawing project is a tool which fits more on artists' requirements (Schkolne 2001). It provides the functions of line-drawing and doodling to create 3D models. By repeated uses of various physical hand tools, users can get instant feedback of moving, extending and deleting objects. The specific modeling method is getting closer to the behaviors of artwork creation. Compared to our tool, it is more complicated and has more constraints. In our modeling environment, we have reduced the complexity by providing two simple tools. For instance, C-StressBall can create objects with different sizes and positions and identify the spatial relationship of objects through pressing a ball by hand. Users can create handcraft-like objects with sense of space in a few minutes.

#### 4.3. USING TANGIBILITY TO ACHIEVE PROPER MODELING OPERATION

Triangles system is a set of tool kit that will integrate digital and physical environment (Gorbet 1998). It allows users to manipulate complicated digital information by hands. By placing the triangle tool kit, the composition of the triangles will be immediately translated into digital data that represent the physical structure and organization of the units. Compared to our C-StressBall and C-BenchWhirler, we are reaching an intuitive operation by sorely pressing, moving and rotating objects. In our daily life, the action of pressing is usually indicating volume control. Just like calligraphy, more pressure the brush is placed, larger the spot is. Calligraphy writing expresses the aesthetics by the tracks of pressure and directions. The design of C-BenchWhirler is trying to emulate to the experiences of turning table in daily life. By a natural and intuitive way, users could realize how to control the rotation of a virtual object with proper strength of hands.

Our research is not to addressing the precision of the data, but to realize how to improve the design development by tangible media in the early phase of design process. In the project of Surface Drawing, it provides too many options of tools that might cause heavier mental loading for users while switching the tools (Schkolne 2001). It is relatively complicated to use. Nevertheless, we are trying to provide an intuitive and easy way for users by addressing the most efficient modeling operation modes.

#### 4.4. THE MEANING OF DIGITAL INFORMATION OF TANGIBLE TOOLS

Physical units are very recognizable and meaningful in the physical world. Playing with the units would provide instant interactions with tangible senses and actions. Adjusting the weight center, balance and the external force on the objects would allow subtle and tender control. The application of C-StressBall and C-BenchWhirler in fact does not only help to understand the geometrical relationship but also extends your emotional senses onto the

objects you create. It will train the users a new skill and provide a brand new experience in creation activity. The rich interaction with the digital media does help in convey the original ideas of the designer.

This research is trying to transfer physical objects from passive units to proactive tools. They can be recognized and interpreted as composition and organization structure by computer system. Furthermore, they can be manipulated subtly. In the case of Triangle, simple triangle units are applied (Gorbet 1998). All the physical units relate to certain digital information behind the scene.

We are providing a solution to handle digital information by human hands which matches to the creative work in the physical world. Eventually, two students from the design school are recruited for an informal testing, Figure 7. One of them is quite familiar with 3D software. The other is a novice for 3D application. Only in two minutes, both designers develop interesting concept models, Figure 8. In the process, the designer uses the ink spheroid which C-StressBall. At the beginning of the experiment, ink spheroids are displayed with the structure of the form. Based on the form structure, the target is changed to focus on the details. Designer starts using more small spheroids in order to refine the form. The design outcome matched their imagination and was not limited in their initial forms. After using C-StressBall to create concept models, the designer can achieve a proper model through the consideration of volume and size. Surplus spheroids produced in the design process are also valuable for a designer. They offer development-oriented possibilities for the design. C-StressBall and C-BenchWhirler successfully helped in getting easier and more direct interaction with 3D virtual objects and handling them better in virtual space.



*Figure 7.* The participants in an experiment

## 5. Conclusion

This system is only utilizing the existing “sphere” modeling function in Maya. Through tangible operation, COMOEN provides high level design capability and reaches high efficiency in modeling. A round shape provides

a good sense of sight and simply represents the relationship of the mass in the design process. Traditional modeling methods using clay and cardboard take a lot of effort. In COMOEN, it is easy to operate and help a designer to present the concept more easily.

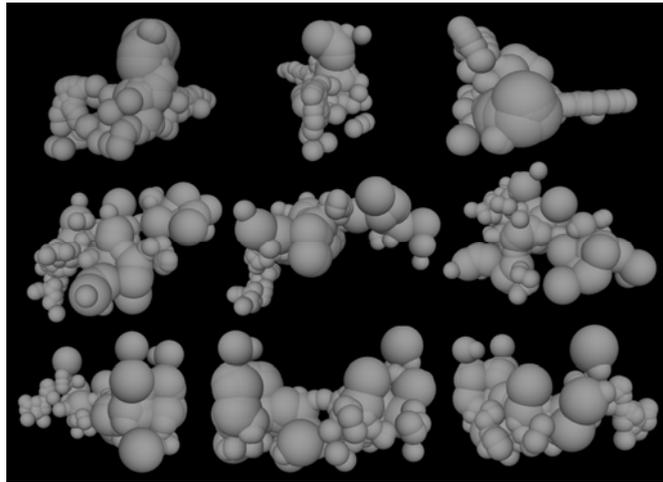


Figure 8. Subjects shaped in COMOEN

COMOEN integrates tangible tools for the spatial modeling behaviors. With C-StressBall and the viewing options provided by C-BenchWhirler, they provide a new conceptual modeling method with touch senses enhanced. We also emphasize that both of the modeling actions are needed in our physical environment. This system provides a new channel for the communication between designer and CAD system. It is a rather intuitive interaction implemented from tangible interface that would make designers manipulate as operating simple physical tools. We find the strength of using the senses of touch. The touch senses succeed in impelling the designer to have their design details more thoroughly.

In our implementation, a working prototype is used to present the possibility. In technology side, all we use is common and ready-made components. Through the meaningful tangible manipulation provided here, we could leave out GUI manipulation. Instead, it would promote itself with high level creation along with CAD system. In the near future, the technology of image recognition and hand sensing will be integrated.

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