SOLVING DESIGN PUZZLE WITH PHYSICAL INTERACTION

A Collage Table Implementation

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Abstract. Design process can be treated as a puzzle exploration process. With puzzle exploration as the interactive metaphor and mechanism, design collage reframes the design visual information as an interactive puzzle-solving game. Based on the design puzzle researches, this paper adapts an intuitive interface approach - physical interaction. A system using multi-touch technology (FTIR) called Collage Table has been implemented as the device to combine a design collage game with the physical interaction. The mechanism for invoking the search is developed and elaborated, and the implementation (both in software and hardware) and possible interaction are also documented in this paper.

1. Introduction

1.1. BACKGROUND

Adapted from the concept of design process as a puzzle-making process from Archea (1987), design puzzles proposed by (Chang, 2004) represent a computational mechanism to model in-direct visual exploration. Chang (2004) integrates the concepts of Woodbury and Archea, and makes the puzzle as a metaphor, then defines the model of integration of design process and puzzle game: *design puzzle*. Design puzzle is comprised of *hints*, *rules* and *goals*. Design puzzle represents the representation of design and the concept of puzzle exploration (Chang, 2004; Lin et al., 2004; Yang et al., 2004). In addition, *design collage* adds the visual manipulation to realize the control of design puzzles.

 Recent years, the physical user interface has gained some advanced results due to new media technologies such as tangible interface. People can use their intuitive devices (hands) for manipulating objects directly. Physical objects offer stronger affordances than purely visual ones. Interactions with more than just one finger is often called *multi-touch* interaction that may allow many people to interact cooperatively in the same physical interface (Han, 2005; Rekimoto et al., 2001).

With multi-touch, interaction can make users to focus on what they want to do not how they are doing. *Physical interaction* especially in design collage, the table is the most popular implementation. For example as (Fails et al., 2005), making a physical interaction table and increasing the children's ability and creativity on storytelling. As Cheok et al. (2006) is also based on the table, and doing a MR (Mixed Reality) to make people to regain the experiences in natural interactions.

Furthermore, interaction has the characteristics of intuitional, instant and direct reaction, and that is especially obvious in the physical interaction technology of multi-touch and sketch. Most famous in the study of multi-touch is Jefferson Y. Han in New York University. He uses the technology of FTIR (Frustrated Total Internal Reflection) and implements a low-cost multi-touch sensing interface (Han, 2005). If the sketch is performed through the touch, the multi-touch is more performance to represent the sketch. The current sketch technology has already been able to transform the 2D drawing into the 3D object or 3D character animation in the development, such as (Igarashi et al., 1999; Mao et al., 2006). We will use the FTIR technology to make a physical interface with the multi-touch and the sketch.

In the scope of this paper, it is based on (Lin, 2004; Yang, 2004), focusing on modifying them to turn into the physical interaction - *Collage Table* through these requirements in the physical interaction mechanisms.

1.2. PROBLEM AND OBJECTIVE

When designers are engaged in design, they meet the losing, bottleneck and puzzled phenomenon. The process is ill-defined beforehand even though the objective has been known, and we can only solve the ill-defined problem by using the hints. If designer lacks the tools or methods for design exploration, hence he/she can't get enough hints. Or in the design exploration process, the designer lacks the interested characteristics, so he/she will feel bored that. Finally, the designer will stop sustained searching the other possibility of plan, or will give up the probable design. So the designer is satisfied with the current result, perhaps which is a fail design.

According to these researches of Lin and Yang, the objective of this research is implementing the physical interface of multi-touch, and will use the design collage game to study the user interactions and feedbacks. We hope to provide the designer with a working environment that can do the thought of design concept, solving the design puzzle, and playful design.

2. Collage Table - a Visual Interaction Game for Representing Design Puzzle

This paper is the concept of design puzzle to construct the physical Collage Table. Design puzzle has three elements: hints, rules and goals. We modify the figure: *the concepts of design collage exploration* from (Yang, 2004) to become as the following figure (Figure 1). We make the designer's abstract idea using amount of visual information (images) to do an intuitive and direct visual representation to form the hints for exploration. Exploration process needs rules that decide the goal achievement. The designer can adjust images to change the representation in visual weight or difference through the physical interaction interface, and the system will give designer visual feedback. The *result* of visual feedback is a representation state that

can be a hint for next exploration. This is a repetitive exploring process until all images are satisfying designer, and then finish an experience of design exploration.
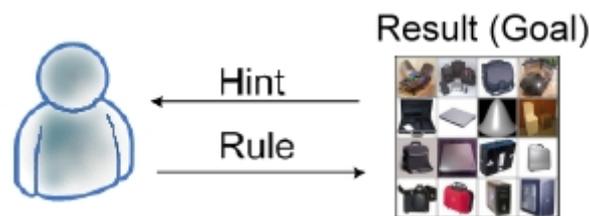

Figure 1. Design collage game exploring concepts.

2.1. EXPLORATION MECHANISM DIAGRAM

According to *the exploration mechanism of design collage* diagrams described in Yang (2004)'s master thesis, we further amplify the concept of collage games as following:

a) To use the design collage implements the design exploration. Because the design collage is like the real collage game, we can apply the physical interaction in the implementation, and to achieve a better metaphor.

b) In the process of Concept Input, it should be able to provide the designer with the direct and instant sketch. In order to reduce the actions that designer finds out additional tool or interface to sketch and input. So we make the procedure simple, the design process can proceed without interrupted in the period.

c) In the process of Interpreter, that should not make all Concept Inputs to become the 4×4 size via Interpreter. That should be judged according to the amounts of sketch and keyword. If designer sketches out five drawings, the collage will show the hints in the 5×5 size. So we provide designer with more rational and effective hint.

d) Yang used the Rule Exploration to limit the exploration activity from the designer. That should make designer to have more freedom to carry out more exploration. So the behaviors of manipulation should be more similar to real collage game in the interface. For example, the actions are including: random selection, movement, scale, rotation and collage them.

e) When designer goes into the collage exploration (play the collage game), that should be able to random arrangement and collage. It can be become the 7×8 size, 8×8 size or even random size. So that will be most alike to play a game or to do the design, the designer can find out more possibility and experiences.

With these five modifications, the exploration mechanism of design collage diagram has been changed through the requirements for a better interaction. The diagram has turned into *Collage Table System mechanism diagram* for this paper as shown in Figure 2.
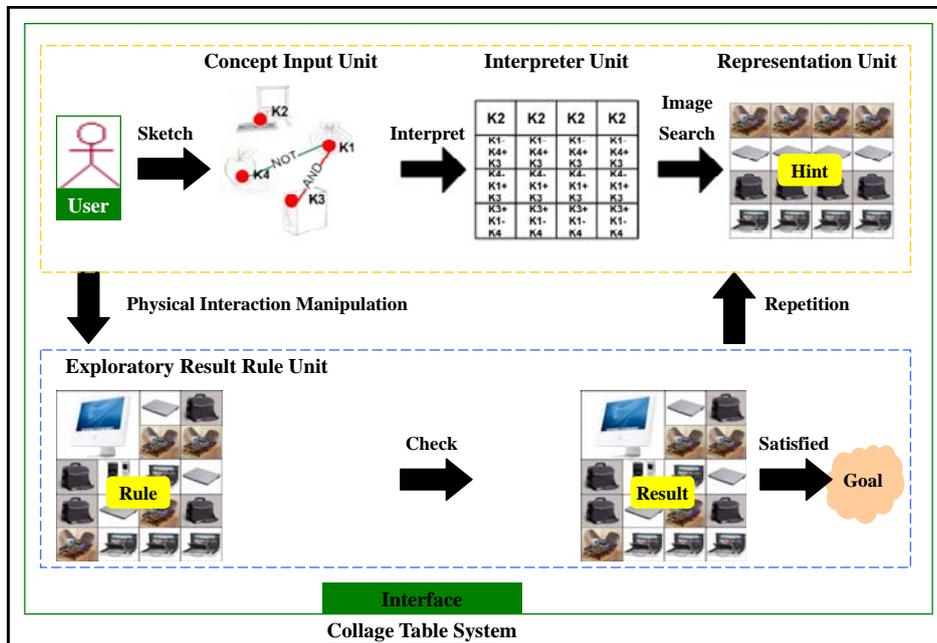
Figure 2. Collage Table System mechanism diagram.

2.2. SYSTEM MECHANISM

According to (Lin, 2004; Yang, 2004), they mentioned that there are four units in the exploration mechanism of design collage. We modify them to apply to Collage Table System through the exploration requirements in the physical interaction. These modified details are described in the following sections. The system mechanism will become the four main units: 1) Concept Input Unit, 2) Interpreter Unit, 3) Representation Unit and 4) Exploratory Result Rule Unit.

2.2.1. Concept Input Unit
The designer can be intuitional and direct to sketch out abstract concepts of design via the physical interface. The purpose of this unit is providing an input interface to lead the designer to express their abstract concepts, and then getting their design knowledge structures. One example is shown in Figure 3.
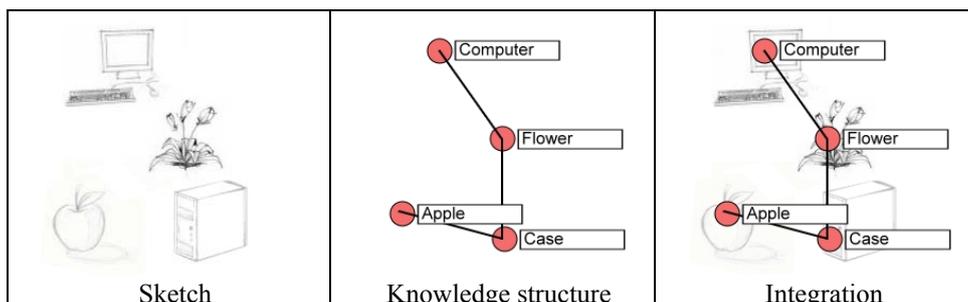

Figure 3. Concept Input Unit.

2.2.2. Interpreter Unit

The purpose of this Interpreter unit is explaining the design knowledge structures from Concept input unit to become a computable way, and this unit is mapping to Representation unit. Through the design knowledge structures, this unit is getting three parameters to operate. Three parameters are: 1) total of keywords (drawings), 2) logic relation of keywords (And or Not), and 3) location orders (top-down and front-rear). The interpretive result is a series of "keywords + simple logic", and storing into the two-dimension array for sending to Representation unit to use.

The total of keywords has the effects on the size of two-dimension array and the amount of collage images in the Representation unit. The logic relation of keywords is the searching way in Google image search. The location orders are including: order of keywords and order of linked-lists. First, the order of keywords is the location of top to down. Second, the order of linked-lists is the order of front node to rear node. The location orders are mapping to the arrangement of the collage images in the Representation unit. The following figures (Figure 4) to illustrate the transformations from Concept input unit to Interpreter unit.
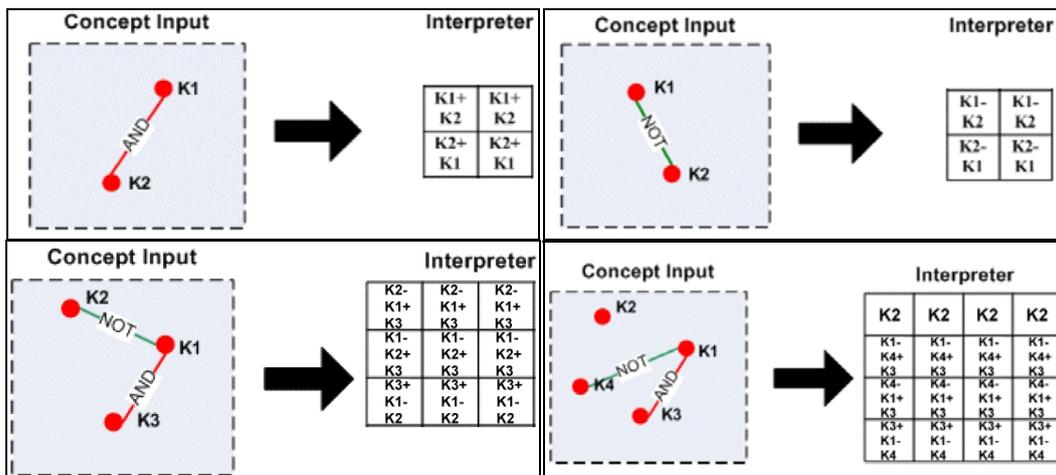

Figure 4. The transformations in the Interpreter unit (from left to right and up to down): 1) Two keywords have the AND logical relation. 2) Two keywords have the NOT logical relation. 3) Three keywords have the AND & NOT logical relations. 4) Four keywords have the AND & NOT & no logical relations.

2.2.3. Representation Unit

The purpose of this unit is providing a representation interface to execute interpretive result. Executing process is integrating search engine to search images, then to download the image information in order according to the array, and finally to paste the images on the interface to finish the initial design collage for forming a hint to be explored (Figure 5).
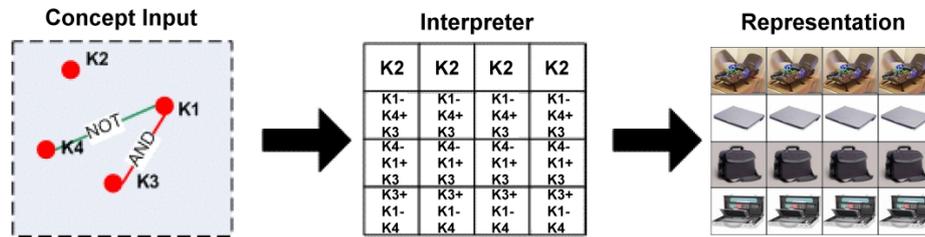
Figure 5.   The representation of design collage.

2.2.4. Exploratory Result Rule Unit

The purpose of this unit is adding the interactive actions for playing collage game in the collage representing interface to go the further design exploration. Exploratory Result is produced via the *rules judgment* through the playing the game on the physical interactive Collage Table. This result will be become a new hint to bring next new exploration. User can use selection and movement to pick the interesting images. When the image is moved, the blank space shown on the gird of design collage will represent the other images in the same place instead through the original image's keywords searching. User can also do the adjustments of scale and rotation for the interesting images, and do the arrangements and collages on the Collage Table interface. This system will run the rules judgment: if all images have already arranged and collaged to form a complete rectangle on the right *Collage area* in the interface. This showed that we have already explored a kind of result.

3.   Implementing a Physical Design Collage - Collage Table

We implement a physical design collage upon the concept of design puzzle - that is like a Collage Table. We can play the collage game to get the design thoughts and to do the design explorations. Collage Table is a physical interaction to go into playful game, and further to assist the design activities.
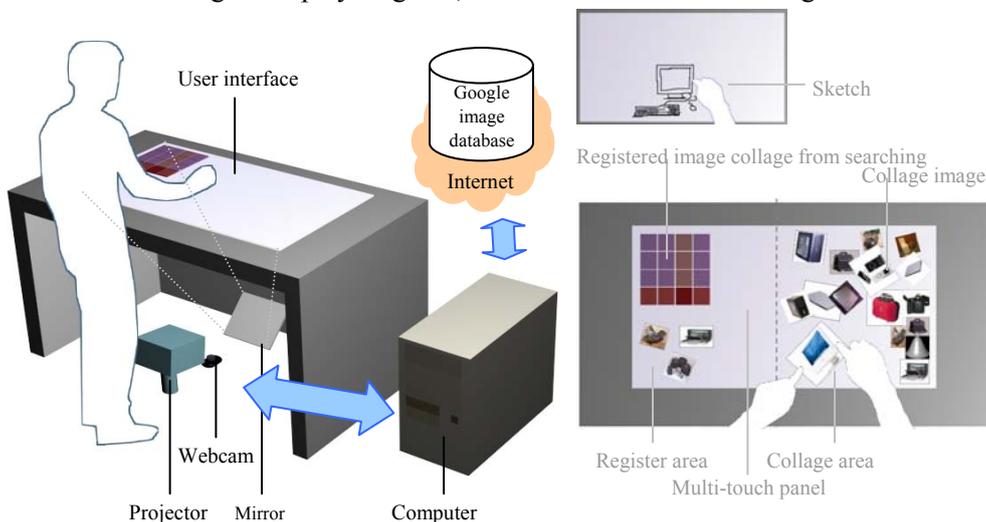
Figure 6. The components in the Collage Table (from left to right and up to down):
1) The component units. 2) User interface 1. 3) User interface 2.

According to the above figure (Figure 6), the components in the Collage Table are including:

    a) User interface. In the Collage Table, the user interface is made a multi-touch panel through the FTIR technology. The designer can sketch out drawings of own design concepts on the multi-touch interactive interface. The user interface has left and right area and they are *Register area* and *Collage area*. Register area is showing registered image collages from searching, and user can also take these needless images to put them on this area. Collage area is a game area for playing the design collage game, and user can also put many collage images on this area. It can display the system picture and game process to increase the intuitional, instant and direct interaction experiences in the user interface.

    b) Google image database and Internet. This component is an existing Google image database. It has already established on the Internet and we will use the keywords to search these images from it.

    c) Computer. Computer is an important unit to operate, compute and integrate.

    d) Projector. It is an output device to project the system content.

    e) Mirror. Mirror is reflecting the picture on the multi-touch panel in the Collage Table from Projector.

    f) Webcam. Webcam is an input device that set up under the desktop to capture the touching actions on the multi-touch panel, and then it will deliver these captured data to computer.

The real Collage Table System's user interface is shown as the following figure (Figure 7). The system comprises three main functions (interfaces). It is including *Sketch interface*, *Keyword Tag & Logic interface*, and *Design Collage Game interface*.
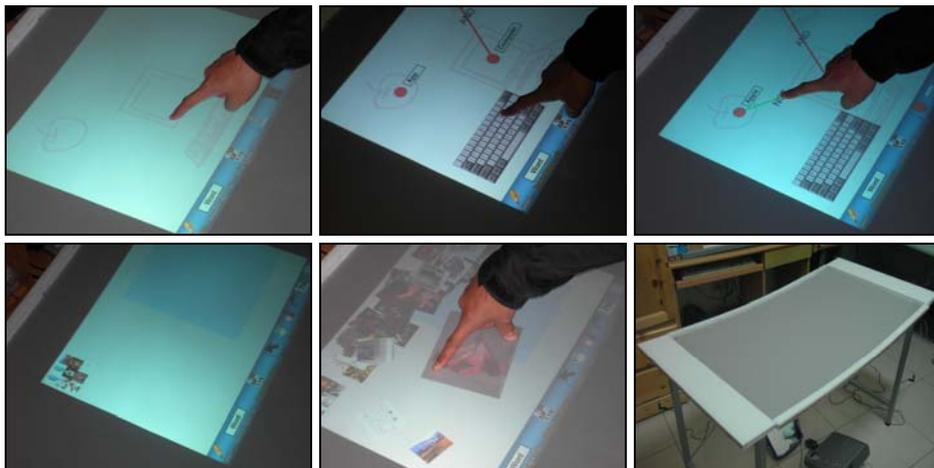
Figure 7. The Collage Table System's user interfaces (from left to right and up to down):
1) Sketch interface. 2) Keyword Tag & Logic interface 1. 3) Keyword Tag & Logic interface 2.
4) Design Collage Game interface 1. 5) Design Collage Game interface 2.
6) The Collage Table hardware.

4. Conclusion

A physical table with design collage built-in has been implemented and tested for understanding the possible interaction of manipulating collaged images (hints). We use the design collage game model to implement a physical interactive interface in this paper. The mechanism for guessing how the manipulation over collaged images has been elaborated based on previous works done by (Yang, 2004). The nature of games and multi-touch environment has brought the playful experience to the users of Collage Table. For the first implementation, the gaming environment has accomplished and need further development in the content related to design. Further research, how such interaction can be mapped to design context and what kind of design context is suitable using design collage will be the next step towards developing a useful tool for solving design puzzles. Furthermore, by testing more game-like design puzzles using the same interface, we hope to establish a playful design environment for assisting the design process.

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