IDEA HITCHHIKING IN THE IDEA ASSOCIATION PROCESS

Exploring the transformation process of design ideas during the conceptual design stage

IH-CHENG LAI
Chaoyang University of Technology, Taiwan

Abstract. Idea association is an important behavior to generate diverse ideas during the conceptual design stage. In the idea association process, the designer links and generates related ideas in conjunction with other participants by idea hitchhiking. By looking for combinations, more novel and useful ideas are found. For understanding how ideas are hitchhiked and combined, we apply a computational tool called DIM and conduct a design experiment to approach this research. Through the analysis of the generated graph-like structure (called idea map), some observations are found and discussed in this paper.

1. Introduction

Design is an interactive endeavor involving the evolution of ideas between two or more participants in discussion, especially during the conceptual design stage. *Idea association* is an important behavior for generating diverse ideas through the dynamic exchange of varied knowledge possessed by the participants (Osborn, 1963). During the design process, designers first apply idea association to generate ideas, which then inspire other participants to generate other ideas by building on other ideas (or *idea hitchhiking*). By looking for combinations, more novel and useful ideas are found (Lugt, 2000). These ideas will serve as leads to development of possible design alternatives or solutions towards diverse problems (Petrovic, 1997; Lai, 2005). Therefore, idea association can be regarded as the first step to trigger the interaction among the participants.

Since ancient times idea association has been considered an important technique in linking internal human thought with the external living environment (Rapaport, 1974). In the design domain, idea association focuses on the process of "linking" among distributed knowledge (Lai, 2005;

A Dong, A Vande Moere & JS Gero (eds), CAADFutures'07, 557-570.

Lai and Chang, 2006). By linking the designer's long-term memory internally and the various participants' knowledge externally, diverse design ideas can be generated. In the linking process, idea hitchhiking is an important guideline to link and generate new ideas in conjunction with other participants' ideas that have been generated (Osborn, 1963).

Therefore, idea hitchhiking focuses on the transformation process of design ideas. This transformation process, which one idea leads to another idea, depends on their relationships. Goldschmidt (1995) and Lugt (2000) indicate that the relationships among generated ideas play an important role in the idea association process. They call such relationships as *design move* and *linking* respectively. In the computational domain, such transformation process implies the transformation among the design states.

2. Transformation Process within Idea Hitchhiking

According to our pilot studies, there are two levels of transformation process within idea hitchhiking: idea level and participant level (Figure 1). The three principles of idea association provide the transformation of design states of ideas through reminding in the idea level. The three principles (including *similarity*, *contrast* and *contiguity*) are originally identified by the Ancient Greeks. In the participant level, role-playing supports the transformation of design states of participants through communication. Through the two levels of transformation process, designers seek combinations among the hitchhiked ideas in order to develop possible design solutions.

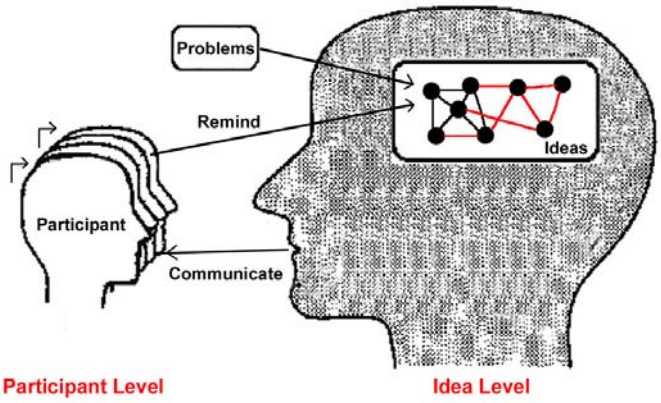

Figure 1. Two levels of transformation process: participants and ideas

Ideas need to be somewhat related to the task at hand and they need to provide some kind of a solution (Lugt, 2000). Thus an idea can be considered as a solution for solving a specific problem within a given task. For solving the design problems, designers are used to decomposing a design

into several architectural elements and using the attributes of these elements as keys to search for relevant ideas within a particular design case (Maher et al., 1995). They also are unique in their capacity to use symbols to represent the meaning of ideas and to construct relationships between ideas that explain how things appear or function.

2.1. USING THREE PRINCIPLES OF IDEA ASSOCIATION

As mentioned before, the three principles of idea association: similarity, contrast and contiguity, are used to link ideas (Lai, 2005). Similarity principle links ideas with similar attributes; conversely, contrast principle links different ideas based on their dissimilarity. The reasoning relationship between different ideas can be linked using the contiguity principle. However, these principles can differ according to the context and type of ideas that are exchanged.

In the idea association process, designers apply the similarity principle to remind design ideas with 'similar' solutions. However, the contiguity principle can be applied to find the same solutions for ideas with different design problems. Because designers often describe design concepts using conceptual vocabulary (Oxman, 1994), contrasting conceptual vocabulary can be used to remind contrasting design ideas, such as public and private, solid and void, linear and center, etc. These three principles, which embody the different relationships among the ideas, provide the mechanism of transformation process of design ideas.

2.2. USING ROLE-PLAYING

Idea association involved dynamic action and reaction of the participants' internal and external knowledge through communication. In the idea association process, designers always play the different roles and then utilize the different principles described above to connect and generate diverse ideas. For example, when designing a house, designers sometimes play the role of the client to link conceived ideas with a real-life situation, before slipping back into their primary role of designer and exploring further design possibilities suggested by the experience.

There are two kinds of interactions within the role-playing: internal interaction and external interaction. In the internal interaction, each participant plays different roles and uses different principles to link ideas to the long-term memory. To generate ideas in conjunction with those of other participants, each designer interacts with the other participants as well as the external design situation in the external interaction. This interaction also directly encourages the designer to play different roles and use different principles to link their ideas. The two interactions follow a sequentially ordered process for exchanging information.

2.3. SEEKING COMBINATIONS

Through the two levels of transformation process within idea hitchhiking, the hitchhiked ideas provide designers the guideline to look for combinations. Therefore, more novel and useful ideas are found. These ideas will serve as leads to development of possible design alternatives or solutions towards diverse problems. Simultaneously, most ideas can be improved upon by modifying their attributes. In our previous design experiment (Lai, 2005), a designer combined three related ideas to develop a design alternative for solving the circulation problem in a brainstorm meeting. The three ideas are "floating space", "elevator entrance" and "courtyard" which are inspired from the design cases of Villa Savoye by Le Corbusier, Maison a Bordeaux designed by Rem Koolhaas and the traditional Taiwanese row house respectively (Figure, 2).

Due to the characteristics of the transformation process (such as reflection, correlation and confliction), it is hard to understand how design ideas are hitchhiked and combined in the real design situation. Therefore, this paper adopts a computational tool called DIM (Dynamic Idea Maps) to understand the mechanisms within the transformation process as well as find some computational advantages for supporting idea hitchhiking under real design situations.

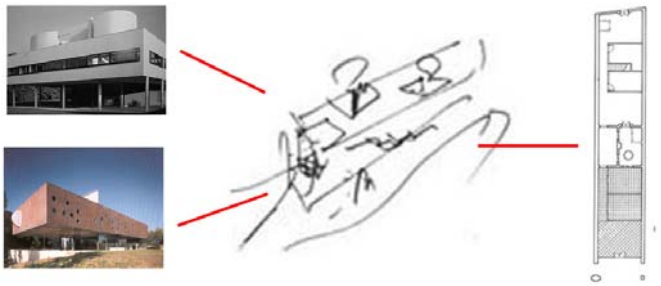

Figure 2. An idea sketch inspired from three design cases

3. DIM: A Design Tool for Representing the Transformation Process of Design Ideas

DIM proposed by Lai and Chang (2006), which applies the mechanisms of case based reasoning (CBR) and software agent (agent), is a computer-support system for supporting the distributed linking in the idea association process. Through linking distributed and related ideas automatically, a graph-like structure (called *idea map*) of nodes (ideas) and arcs (links) is generated (Figure 3). The idea map, which represents the transformation process of ideas and their relationships, help us approach this research. Its components and technologies are described in the following sections.

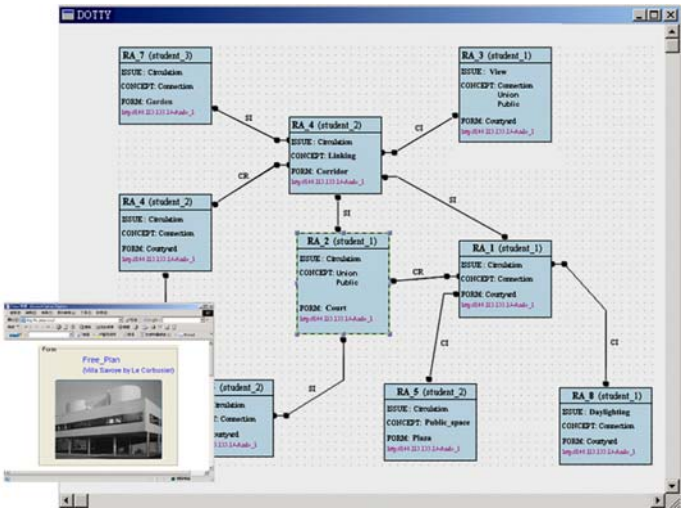

Figure 3. A generated idea map

3.1. DIM COMPONENTS

DIM includes two kinds of components: agent entities and design knowledge. Agent entities are assigned to different sub-tasks that are decomposed from a specific design task. According to different design situations, these agent entities collaborate to generate design ideas and links. There are five types of agent entities: role agent (RA), user agent (UA), director agent (DA), stage agent (StA) and scene agent (ScA). Each RA has the reasoning skill and memory to link and generate ideas. The ScA controls the list of RAs and time duration in each scene. StA is in charge of storing the design outcomes. UA and DA are regarded as the user interfaces that provide human designers to interact each other in the DIM environment. Through the DA or the UA, participants (human designers) can individually load different RAs to play (linking and generating ideas) in sequential scenes which are controlled by ScAs. The design outcome (an idea map) in each scene is automatically stored in the StA's repository.

Three kinds of design knowledge support the behaviors within agent entities mentioned above. They are *knowledge*, *principles* and *linking process*. Knowledge represents design ideas and memory organization within agent entities. Principles provide the capability to allow agent entities to link diverse ideas dynamically. Through linking process in the internal and external interactions, these agent entities can interact various design situations dynamically. The details are described as follows:

1. Knowledge: In DIM, ICF (issue, concept and form) schemata proposed by (Oxman, 1994) mainly represent knowledge within RAs' long-term

memory. Through integrating the three principles of idea association, each RA's knowledge includes a set of maps: an *ICF map* for installing various ideas and three *knowledge maps* functioned as dictionary. The knowledge maps are the *issue map*, the *concept map* and the *form map*.

2. Principles: three principles provide RAs' reasoning skills to link ideas. The three principles are similarity, contrast and contiguity. Based on the ICF knowledge representation, each principle has an individual mechanism for textual matching to link diverse ideas within various RAs' ICF maps.
3. Linking process: according to different design situation, the linking process provides various communication ways among agent entities in two kinds of interactions: internal and external. These agent entities can dynamically interact with each other based on the mechanisms of Agent Communication Language (ACL) (Wooldridge, 2002).

In addition, the *script* is the main structure for describing sequential events including the list of RAs, the acting of RAs, performing time duration and so on. Through the sequential events, the agent entities interact dynamically each other in different design situations.

3.2. DIM TECHNOLOGIES

The multi-agent environment of DIM is implemented on top of JADE (Java Agent DEvelopment Framework) (JADE, 2005) with JESS (Java Expert System Shell) (JESS, 2005) as the reasoning engine inside the agents. The ACL among these agents is based on the FIPA (Foundation for Intelligent Physical Agents) communication language (FIPA, 1999). In DIM, each UA (including DA) has an individual FIPA platform to control these agents. These FIPA platforms are communicated by using the HTTP message transport protocol to exchange ideas emanating from different geographical locations.

4. Design Experiment

The design experiment was held in a computer laboratory (Figure 4). In the experiment, we chose three architecture students (fourth grade) as participants to keep the group process simple and observable. They were $Student_{\_1}$, $Student_{\_2}$, and $Student_{\_3}$. We expected the group members to be very fluent in the idea association process. They were accustomed to working together. All participants with similar design domain knowledge were familiar with the DIM environment.

Figure 4. The design environment

The purpose of this meeting was to develop design strategies for the spatial organization of a single-family row house by generating ideas during the conceptual design stage. The duration time of the meeting was 10 minutes. The addressed design problem was daylight. Besides, the three participants were asked to insert three additional role agents (RAs) to help in the design task. Three RAs inserted by Student$_1$ are RA_1, RA_2 and RA_3. Three RAs inserted by Student$_2$ are RA_4, RA_5 and RA_6. Three RAs inserted by Student$_3$ are RA_7, RA_8 and RA_9.

In DIM, a design task of linking ideas is called *play*. A play includes three steps: initializing a play, editing a script, and directing a play. Each step has its individual window for participants to input related information. Additionally, only DA can edit the script of the design knowledge of ScAs and StA. In the play, Student$_1$ is the DA. Student$_2$ and Student$_3$ are UAs. The order of generating ideas is Student$_1$, Student$_2$, and Student$_3$.

4.1. INITIALIZING A PLAY

There are two steps in the initialing play: loading agents and linking agent platforms. In the step of loading agents, each participant loaded his agents that will join this play by inputting the agents' AIDs (agent identities) and their Java class paths. For example, Student$_1$ should load and input the information of a StA, a ScA and three RAs. In the step of linking agent platforms, the three participants added remote agent platforms of other participants. Through HTTP message transport protocol, they exchanged ideas emanating from their JADE agent platforms. These agents in the

different JADE agent platforms can be visualized and controlled through the Agent Management GUI (Figure 5).

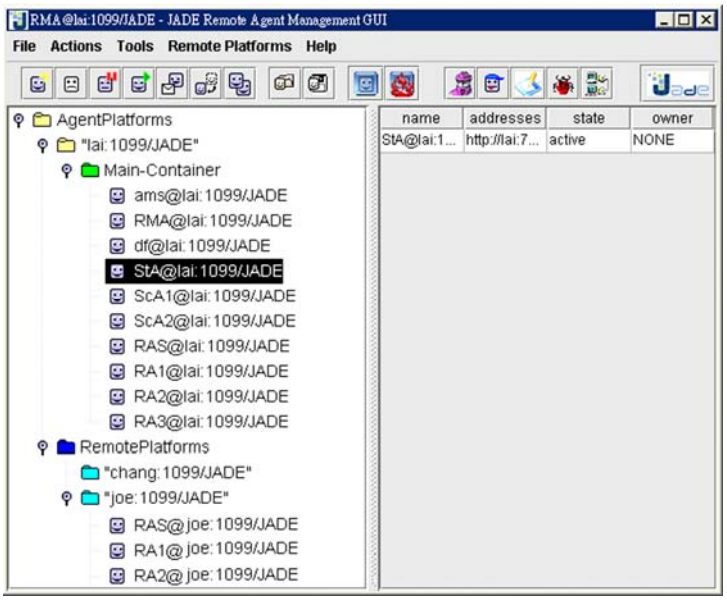

Figure 5. Agent Management GUI

4.2. EDITING A SCRIPT

After loading agents and linking agent platforms, Student$_1$ should input the design knowledge of StA and ScA through the Script Editor GUI (Figure 6). Student$_1$ first input the AID of StA (StA@lai:1099/JADE) in the Receivers slot. He also input the information in the Content slot. The information included the design task (row_house), the design problem (daylight) and the duration time (10) (seen in Figure 6). In the same slots of the Script Editor GUI, Student$_1$ then input the AID of ScA and the ScA's information including the design problem, the duration time, the number of RAs and RAs' skills (similarity, contrast or contiguity).

4.3. DIRECTING A PLAY

After Student$_1$ finished editing the script, Student$_1$,, Student$_2$, and Student$_3$ started to generate design ideas. Student$_1$ first input the information in the Content slot in the Script Editor GUI. The information included issue, concept, form, RAs' AIDs and types of principles. Then, DIM automatically generated an idea and a link that connected into the original idea map (seen in Figure 3). According to the order of generating ideas, other participants followed the same way as Student$_1$ to generate ideas and links within the

duration time. When the time (10 minutes) was up, DIM automatically terminated the play. The outcome of the play is shown in Figure 7.

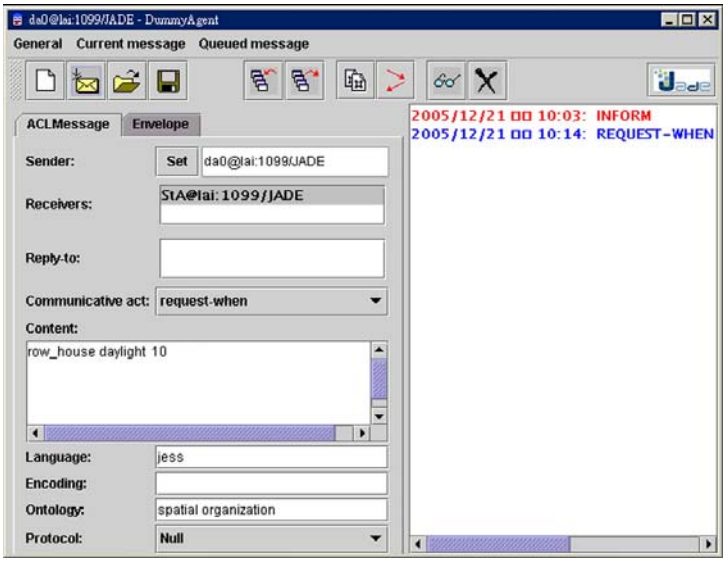

Figure 6. Script Editor GUI

5. Analysis and Observations

In the generated idea map (Figure 7), each box as an idea includes four kinds of information. They are the AID of RA that generates this idea and the ICF (issue, concept and form) value within this idea. Each arc (or link) between the two boxes represents a kind of relationships including similarity (SI), contrast (CR) or contiguity (CI). For example, the idea (in the right bottom corner) is generated by RA_8. The value of ICF is daylight, interaction and hole, and cutting wall and URL which can be hyperlinked to a specific design case (seen in Figure 3). This idea has three links (SI) which connect to other three ideas generated by other RAs (RA_5, RA_1, RA_1).

In order to understand the mechanism of the transformation process, participants used the generated idea map to seek combinations. Each participant was asked to develop two more design alternatives for solving the problem of daylight in 20 minutes by drawing idea sketches (Figure 8). According to their design alternatives, they should individually frame the range of the selected ideas and their relationships (dotted-line area in Figure 7) in this idea map. In the framed range, the ideas and different types of links are labeled and numbered for our analysis. The meeting process was also recorded on videotape to complement insufficient information of the analysis.

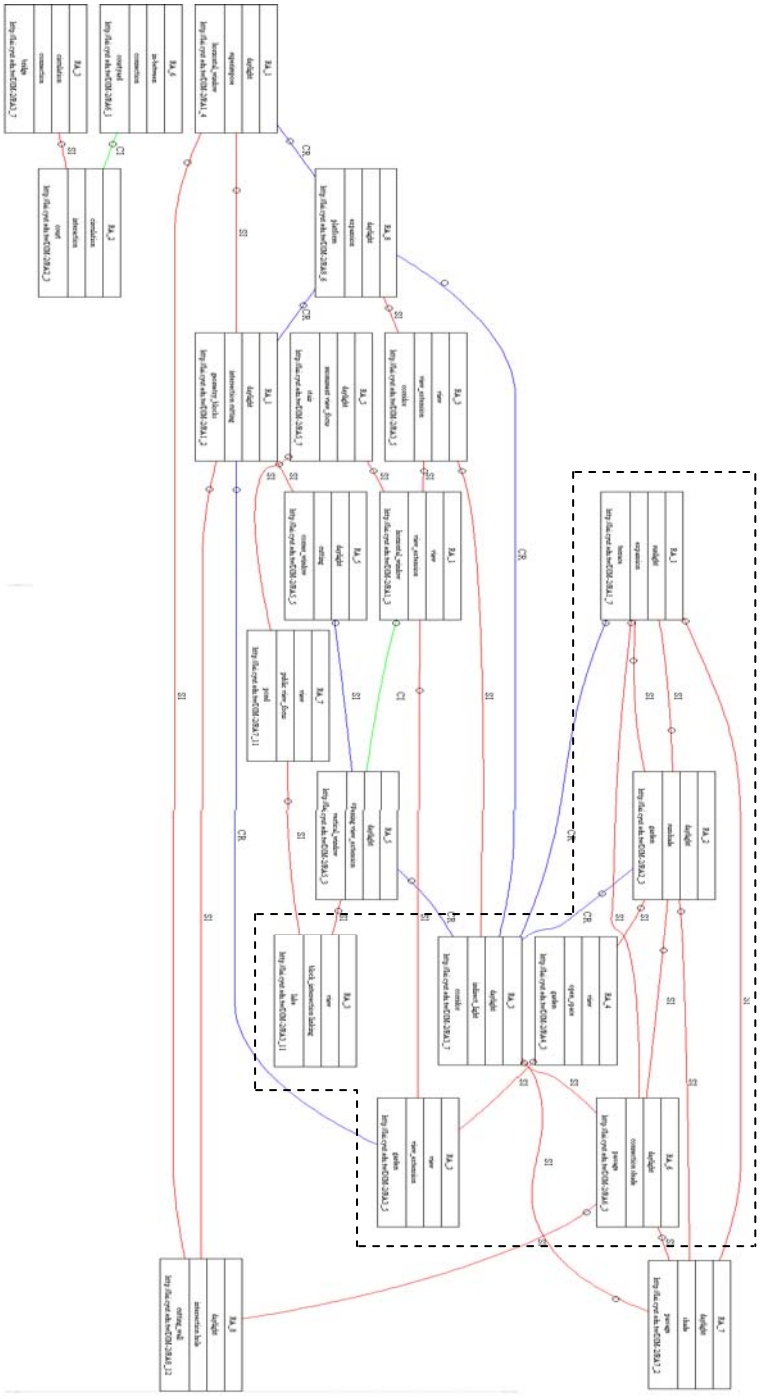

Figure 7. The generated idea map and the framed range (dotted-line area)

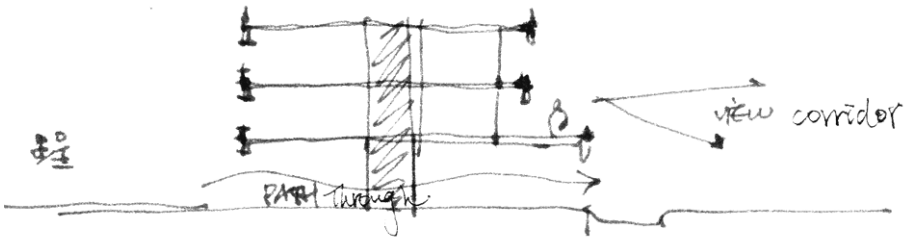

Figure 8. An idea sketch by Student_1

5.1. ANALYSIS

In this experiment, the participants generated an idea map including 21 ideas and 34 links (seen in Figure 7). Within the 21 ideas, there were three new design problems (issues) and 18 new design solutions (concept and form). The three new design problems were circulation, view and ventilation. Within the 34 links, there were 21 similarity links, 9 contrast links and 4 contiguity links.

Based on the idea map, Student_1,, Student_2, and Student_3 developed three, two and three design alternatives respectively through seeking combinations. The number of ideas and links (including different principles of links) within the framed range of design alternatives are shown in Table 1. In the Table 1, the Case 1 developed by Student_1 composes of 5 ideas and 5 links including 3 similarity links, 1 contrast link and 1 contiguity link. Through the analysis, some observations are found as described in the following section.

TABLE 1. The number of ideas and links in different design alternatives

Participants	Student_1			Student_2		Student_3		
Design alternatives	Case1	Case2	Case3	Case1	Case2	Case1	Case2	Case3
Ideas	5	5	5	4	5	7	6	7
Links	5	4	4	4	4	6	6	7
Similarity	3	3	2	2	2	5	5	5
Contrast	1	1	2	2	2	1	1	2
Contiguity	1	0	0	0	0	0	0	0

The transformation process of idea hitchhiking is also related to the transformation of design problems. While the contiguity link is applied to find different design problems with same solutions, the analysis also quantifies the links within the ideas that has the contiguity link. The purpose

is to understand how the designers decide the priority of the design problems. The number of the different types of links within the different design problems is shown in Table 2. In Table 2, the circulation problem has 5 links including 3 similarity links, 1 contrast link and 1 contiguity link. All participants selected the circulation problem as the first priority for problem solving in the next scene.

TABLE 2. The number of different types of links within the three design problems

Problems	Circulation	View	Ventilation
Links	5	3	2
Similarity	3	2	0
Contrast	1	0	1
Contiguity	1	1	1
Participants	Student$_{1}$, Student$_{2}$, Student$_{3}$	No	No

5.2. OBSERVATIONS

The three principles of idea association and role-playing provide the effective mechanisms for the transformation process within idea hitchhiking. Thus, correlated ideas and their relationships can be generated reflectively. When the designer does not agree with other participants' ideas, he/she can dynamically change the roles or principles to solve such design *confliction*. Another important lesson we learned is *consonance*. The ideas with most consonance with others will be selected as a candidate (called *key idea*). The key idea provides an important start point for participants to search (including depth search and breadth search) for other alternative ideas to seek combinations. Besides, several mechanisms of ideas hitchhiking are found as described below.

- Based on the consonance, the combined ideas are below 7 ideas. The number seems to reflect the limitation of working memory, which is proposed by Miller (1956). Besides, these combined ideas mostly compose of more links than other ideas that are not combined.
- Three types of principles have the different functions for transforming ideas. The similarity link and the contrast link offer an important guideline for seeking combinations. The contiguity link provides the indication for participants to decide the priority of design problems.
- The transformation process of idea hitchhiking can be re-used and integrated with the new transformation process. The combined transformation process gives participants another alternative for seeking combinations.

In addition, some computational advantages that support idea hitchhiking under real design situations are found in DIM environment. They are 1) to provide three means for collaboration, including human-to-human, human-to-machine and machine-to-machine; 2) to automatically connect blocked linking processes of idea association and 3) to dynamically add the design knowledge to further the agents' learning.

6. Conclusion

Idea hitchhiking focuses on the transformation process of ideas and their relationships during the conceptual design stage. There are two levels of transformation process within idea hitchhiking: idea level and the participant level. Through the two levels of transformation process, designers seek combinations among the hitchhiked ideas in order to develop possible design solutions toward the problems. DIM provides an effective design tool to understand the mechanisms of the transformation process.

Through the design experiment, some mechanisms (such as design confliction and consonance) within the idea hitchhiking and the computational advantages of DIM are found and discussed in Section 5.2. There is a drawback from our design experiment. It is the information visualization with the complexness of the maps when they come to be real uses.

The research will provide an essential prerequisite of preparation for supporting distributed linking process of idea association in any creative problem solving meetings. Participants (human or computers) can hitchhike and combine related design ideas to serve as leads to development of possible design alternatives without the barriers of geographic limitations and different time zones.

References

FIPA: 1999, Specification part 2-Agent communication language

Goldschmidt, G: 1995, The designer as a team of one, *Design Studies*, 16(2), pp. 189-209

JADE: 2005, http://jade.tilab.com/

JESS: 2005, http://herzberg.ca.sandia.gov/jess/

Lai, IC: 2005, Dynamic Idea-Maps: A Framework for Linking Ideas with Cases during Brainstorming, *International Journal of Architectural Computing*, 4(3), pp. 429-447.

Lai, IC and Chang, TW: 2006, A Distributed Linking System for Supporting Idea Association in the Conceptual Design Stage, *Design Studies*, **27**(6), pp. 685-710

Van der Lugt, R: 2000, Developing a graphic tool for creative problem solving in design groups, *Design Studies*, **21**(5), 505-522

Maher, ML, Balachandran MB and Zhang DM:1995, *Cased-Based Reasoning in Design,* Lawrence Erlbaum Associates, Mahwah, N.J.

Miller, GA: 1956, The magical number seven, plus or minus two: Some limits on our capacity for processing information, *The Psychological Review*, **63**, pp. 81-97

Osborn, AF: 1963, *Applied Imagination: Principles and Procedures of creative thinking*, Charles Scribner, New York.

Oxman, RE: 1994, Precedents in Design: a computational model for the organization of precedent knowledge, *Design Studies*, **15**(2), pp.117-134.

Rapaport, D: 1974, *The History of the Concept of Association of Ideas*, International Universities Inc., New York.

Petrovic, IK: 1997, Computer Design Agents in a Brainstorming Session, *eCAADe'97*, Vienna.

Wooldridge, M:2002, *An Introduction to MultiAgent Systems*, John Wiley & Sons Ltd., Chichester.