Dynamic Linkages between Ideas and Cases
Toward a computational approach for supporting idea association during brainstorming

Ih-Cheng Lai
Graduate Institute of Architecture, National Chiao Tung University, Hsinchu, Taiwan

Keywords: Idea Association, Case-Based Reasoning, Retrieval, Adaptation, Protocol Analysis

Abstract: This research makes use of a cognitive study to explore a mechanism for associating ideas in a brainstorming session. Firstly, we propose a linking model integrating three principles of idea association (similarity, contrast and contiguity) with two processes of case-based reasoning (retrieval and adaptation). For identifying the types and mechanisms of linkages within the linking model, a design experiment and its protocol analysis was conducted. Finally, a framework for case-based reasoning to support idea association called Dynamic Idea-Maps (DIM) is proposed, and its components and mechanisms are elucidated.

1. INTRODUCTION

Design as a creative behaviour is dependent on the evolution of many diverse ideas. The process for evolution of design ideas is often regarded as design brainstorming meetings. Idea association, as identified by Osborn (1963) is an important behaviour in brainstorming for linking and generating diverse ideas during conceptual design stage. Therefore, a computational system for supporting the linkage of idea association is the critical issue for further understanding of design behaviour in conceptual design stage.

In addition, idea association provides some cognitive principles unleashed in this paper. We applied such principles to modelling our computational system according to the needs of supporting idea association during design brainstorming meeting.

There is a tendency to use design cases as references and linking past experience with current ideas for generating ideas during brainstorming. A
computational mechanism, called case-based reasoning (CBR) (Kolodner 1993), promises to support design by reminding designers of previous experiences that can be helpfully applied to new situations (Maher et al., 1995; Chiu, 2001). Retrieval and adaptation are two important processes of CBR to access case bases directly.

By integrating the principles of idea association with two processes of CBR, this research intends to explore the linking relations between ideas and cases. The objectivity is to propose a framework of CBR to support idea association during brainstorming. The principles and CBR processes are elaborated in the following sections.

1.1 Three principles of idea association

Idea association in a brainstorming session is a method by which one idea leads to another idea by a connection made in long-term memory. Three principles of idea association are similarity, contrast and contiguity. In architectural design, designers always decompose a design into several architectural elements, and use these elements’ attributes as keys to look for relevant ideas through these three principles. The mechanisms and their applications are described as follows.

1.1.1 Similarity

Similarity is a notion that elements have attributes in common with other elements. Designers always use similar attributes within architectural elements to generate ideas. For example, in the case of the Frank House designed by Peter Eisenman, the idea “layering walls” comes from the similar wall composition of the Schröder House designed by Gerrit Rietveld (Figure 1).

Figure 1. Similarity between the Schröder House and the Frank House
1.1.2 Contrast

Contrast is the comparison of similar elements to set off their dissimilar qualities. Designers always use contrast keywords to describe the dissimilar qualities, such as inside and outside, private and public, solid and void, light and heavy. In the case of Villa Savoye designed by Le Corbusier, the idea “light structure” comes from an aristocratic town house in Paris through its inversion of the traditional interior spatial system (Figure 2).

![Contrast between Petit Trianon and Villa Savoye](image)

Figure 2. Contrast between Petit Trianon and Villa Savoye

1.1.3 Contiguity

Contiguity involves causal relationships between elements. Design ideas can be generated through responding to the causal relationships of design problems, such as environmental, functional, structural, or other pragmatic conditions. For example, Villa Malaparte designed by Adalberto Libera is built on the edge of a cliff. He created the idea “roof-solarium” in response to the site conditions (Figure 3).

![Contiguity between Villa Malaparte and site conditions](image)

Figure 3. Contiguity between Villa Malaparte and site conditions

1.2 Two processes of case-based reasoning

Two relevant processes of CBR regarding of idea association are case retrieval and case adaptation. Retrieval and adaptation are the way to linking the ideas with design cases. Many researchers examine the application of
analogical reasoning to retrieve and adapt design cases to new cases (Maher et al., 1995; Dave et al., 1994; Oxman, 2004) in different architectural design areas that can be used in realizing our idea association.

1.2.1 Case Retrieval

The recall of a case in CBR is called retrieval. The process of retrieval mainly contains two steps: case comparison and case selection (Tsatsoulis and Williams, 2000). During retrieval, each case must be compared with current problem and be assigned a degree of similarity. Then the retrieving mechanism will select the cases with the highest degree of similarity. To retrieve a case from memory, a CBR system must decide whether it is the most appropriate one for the current situation based on comparing a degree of similarity.

1.2.2 Case Adaptation

The process of changing the old, retrieved solution to fit the current problem is called case adaptation. Dave, et al. (1994) argued that there are two kinds of case adaptation: adaptation and combination. Combination employs the same techniques as adaptation, but the major difference is that two or more cases need to be selected from the case library. Besides, adaptation and combination use different operations to transform old cases, such as deleting, adding, and substituting (Chiu and Shih, 1994; Tsatsoulis and Williams, 2000).

2. A LINKING MODEL BETWEEN IDEAS AND CASES

During brainstorming, ideas need to be related to the design task at hand and they need to provide some kind of a solution besides communication (Lugt, 2000). Through the three principles identified in previous sections, we hypothesize that two processes involve in the process of idea association.

1. Retrieving previous ideas or design cases through comparing current ideas and selecting
2. Adapting or combining current ideas with retrieved design cases or previous ideas

Based on the above hypothesis, we propose a linking model for idea association. The linking model composes of idea entities (I\text{new}, I\text{current}, I\text{previous}, C\text{case}) and different types of linkages. Through similarity ($\mu_s$), contiguity ($\mu_c$) and contrast ($\mu_r$) linking principles, each type of linkages
contains retrieval ($\omega_r$), adaptation ($\phi_a$) or combination ($\phi_c$) functions. Thus, the proposed linking model can be formulated as follows.

$$I_{\text{new}} = \mu \phi (I_{\text{current}}, I_{\text{previous}}, C_{\text{case}}) \quad (1)$$

$I_{\text{new}}$: new idea  
$I_{\text{current}}$: current idea  
$I_{\text{previous}}$: previous idea  
$C_{\text{case}}$: retrieved case  
$\phi$: adaptation function  
$\mu$: linking principle

$$I_{\text{previous}} | C_{\text{case}} = \mu r (I_{\text{current}}) \quad (2)$$

$\omega_r$: retrieval function

$$\phi \supset \{ \phi_a, \phi_c \} \quad (3)$$

Where $\phi_a$: adaptation  
$\phi_c$: combination

$$\mu \supset \{ \mu_{\text{si}}, \mu_{\text{cr}}, \mu_{\text{ci}} \} \quad (4)$$

Where $\mu_{\text{si}}$: similarity  
$\mu_{\text{cr}}$: contrast  
$\mu_{\text{ci}}$: contiguity

Protocol analysis is a useful methodology for exploring the understanding of design behaviours (Ericsson and Simon, 1993). For elucidating the mechanism of the linking model, the following studies were undertaken: 1) conducting a design experiment; 2) studying the process by using protocol analysis, and 3) proposing a computational mechanism for supporting idea association.

3. THE EXPERIMENT

The design experiment was conducted in order to identify the types and mechanisms of linkages between ideas and cases, and to explore a computational mechanism for this linking model described above.

Before the formal test, a ‘warm-up’ exercise was given to ensure that participants completely understand the design task. The meetings were recorded on videotape that was then transcribed into protocols. In the design process, participants applied different media (such as sketches, words, images) to describe their ideas and recalled cases. At the same time, they wrote down their ideas and recalled cases, and numbered ideas chronologically. The documentations were recorded on flip charts that were then posted on the wall.
3.1 Design task

The design task was related to the spatial organization of a row house for a single-family in a historical temple town, and concentrated on developing ideas in the early conceptual design stage. A case library composed of two types of single-family houses was provided: row houses and detached houses (Figure 4). These houses are designed by well-known architects, such as Le Corbusier, Rem Koolhaas, and Tadao Ando. Also, each house has its individual design ideas related to spatial organization. Participants were encouraged to study the cases, and to select these design cases for generating ideas in the design process.

3.2 Participants

We chose three participants to keep the group process simple and observable. We expected the group members to be very fluent in the idea generation process. They were accustomed to working together. All participants with similar design domain knowledge had sufficient skill levels in designing and drawing, and were familiar with the above design cases.

3.3 Process

The meeting shared a general session plan with a total duration of 45 minutes. A design goal was given to each participant before associating ideas. Within this general plan, participants were encouraged to generate ideas without criticizing of ideas. All generated ideas and related documentations were collected for protocol analysis.
4. THE ANALYSIS AND OBSERVATIONS

In this experiment, 23 ideas were generated by these participants. The videotape of the meeting was transcribed into a protocol. Related sketches were pasted into the protocol at the location in which the idea came up. Several domain concept vocabularies (marked in grey) of text that could be ascribed to ideas were selected. Each was given a title as idea name that briefly described this idea. For example, let us look at idea 09 “Placing void boxes”. At this point idea 09 was generated by the designer (L), and he was invited to provide idea sketches. At the same time, the designer (L) recalled a design case ‘Wang’s house’ that was marked in box (seen in Table 1).

Table 1. Sample of idea fragments in the protocol

<table>
<thead>
<tr>
<th>Idea/Person</th>
<th>Idea name</th>
<th>Protocol text</th>
<th>Sketches</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/L</td>
<td>Floating building</td>
<td>L: We can create a floating space for connecting river side and temple plaza on the ground floor.</td>
<td>C: It's a good idea, but it will cause some problems about public domain influences house privacy.</td>
</tr>
<tr>
<td>06/M</td>
<td>Lifting lobby</td>
<td>Villa Savoye has a lifting lobby which can solve this problem.[images]</td>
<td></td>
</tr>
<tr>
<td>07/L</td>
<td>Elevator entrance</td>
<td>Rem Koolhaas has the similar house project in France.</td>
<td>L: I know this project. There is an elevator room in living space. Maybe we can create an elevator entrance on the ground floor.[images]</td>
</tr>
<tr>
<td>08/C</td>
<td>Placing solid boxes</td>
<td>C: See my sketch, we can place solid boxes instead of free columns on the ground floor.[Ideasketch]</td>
<td>M: Interesting! It will cost a lot of money.</td>
</tr>
<tr>
<td>09/L</td>
<td>Placing void boxes</td>
<td>L: How about placing void boxes? It can respond to the traditional urban context. Just like the Wang's house.</td>
<td>C: Wang's house?</td>
</tr>
<tr>
<td>10/L</td>
<td>Connecting solid boxes with void boxes</td>
<td>L: Oh, yes. Maybe we can combine this two ideas: Connecting solid boxes with void boxes vertically.</td>
<td>C: Interesting!</td>
</tr>
<tr>
<td>11/M</td>
<td>Roof garden</td>
<td>M: We can create a roof garden to provide good views of riverside and temple plaza. Like Villa Savoye, the ramp can connect different void spaces in different floors, which create a vertical strolling circulation.[Ideasketch]</td>
<td>L: Oh, yes.</td>
</tr>
<tr>
<td>12/M</td>
<td>Strolling circulation</td>
<td>C: The Gardens can be across by bridges.</td>
<td></td>
</tr>
<tr>
<td>13/C</td>
<td>Bridge across garden</td>
<td>C: See idea 08, we can create a cylinder extending ceiling of arcade to provide a visual focus in street.[Ideasketch]</td>
<td></td>
</tr>
<tr>
<td>14/L</td>
<td>Seeing cylinder in the arcade</td>
<td>L: See idea 08, we can create a cylinder extending ceiling of arcade to provide a visual focus in street.[Ideasketch]</td>
<td></td>
</tr>
<tr>
<td>15/C</td>
<td>Infilling water</td>
<td>C: How about water? Maybe we can infill water on the ground floor for responding river condition.[Ideasketch]</td>
<td></td>
</tr>
</tbody>
</table>
4.1 Types of linkages

According to the fragment of the protocol from ideas 5 to 15 (Table 1), ideas and design cases have dynamic linking relationships in the process of idea association. For generating new ideas (output), a present idea (input) links not only design cases but also previous ideas. Consequently, a complex idea network involving several types of linkages is mentally constructed that inspires participants to generate diverse ideas (Figure 5). Basically, there are two linking directions (forward and backward) that are called forelink and backlink respectively. Therefore, there are five types of linkages in the dynamic idea network as follows.

1. Forelink between ideas: an input idea stimulates a designer to generate the next ideas forward.
2. Backlink between ideas: an input idea makes a designer recall the previous ideas backward, and then is adapted or combined with the previous ideas.
3. Forelink from cases to ideas: a case stimulates a designer to generate the next ideas forward.
4. Backlink from ideas to cases: an input idea makes a designer recall the case library backward.
5. Backlink between cases: a case makes a designer recall another cases in the case library backward

Figure 5. A dynamic idea network
4.2 Mechanisms of linkages

Each type of linkage has its individual mechanism of retrieval and adaptation. By encoding the three linking principles (µsi, µci, µcr) and three functions (ωr, φa, φc), the study used two linking matrices to understand the mechanisms of different types of linkages: a linking matrix among ideas and a linking matrix between ideas and cases. Each cell of the matrices contains linking directions, linking principles, and retrieval and adaptation processes (Table 2 and 3). Besides, the arcs signify the mechanism of the linkage between design cases (Table 3).

Within the two matrices, each cell clearly articulates the mechanism of the linkage. For instance, within the matrix among ideas, idea 09 “placing void boxes” has one backlink with idea 11 “roof garden”, and a forelink with idea 10 “connecting solid box with void boxes”. The forelink uses the combination function (φc) to link idea 09 with idea 10 forward. The backlink uses the similarity (µsi) principle to link idea 11 with idea 09 backward. Besides, idea 09 also has a contrast principle (µcr) linking with idea 08 “placing solid boxes”.

**Table 2. Linking matrix among ideas**

<table>
<thead>
<tr>
<th></th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/L</td>
<td>Floating building</td>
<td>for</td>
<td>for</td>
<td>back</td>
<td>back</td>
<td>for</td>
<td>back</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06/M</td>
<td>Lifting lobby</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07/L</td>
<td>Elevator entrance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/C</td>
<td>Placing solid boxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09/L</td>
<td>Placing void boxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/L</td>
<td>Connecting solid boxes with void boxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/M</td>
<td>Roof garden</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/M</td>
<td>Strolling circulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13/C</td>
<td>Bridge across garden</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14/L</td>
<td>Seeing cylinder in the arcade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/C</td>
<td>Infilling water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Generally, combination (φc) and adaptation (φa) are main functions to link input ideas with cases and ideas forward. Ideas are combined through the congruity (µci) principle, and are adapted through the similarity (µsi) and contrast (µcr) principles. Retrieval (ωr) is the main function in backlinks. Though the similarity (µsi) principle plays an important role for linking previous ideas and cases backward, the contiguity (µci) and contrast (µcr)
principles provide another ways for linking cases backward. Also, in backlinks, the higher degree of similarity plays an important role for retrieving previous ideas and cases.

Table 3. Linking matrix between ideas and cases

<table>
<thead>
<tr>
<th></th>
<th>Villa Savoye by Le Corbusier</th>
<th>Maison a Bordeaux by Rem Koolhaas</th>
<th>Wang's House by K.S. Hsu</th>
<th>House in Brasqueir by Xavier de Geyter</th>
</tr>
</thead>
<tbody>
<tr>
<td>05/L</td>
<td>Floating building</td>
<td>back, μci, φc</td>
<td>back, μyi, φc</td>
<td></td>
</tr>
<tr>
<td>06/M</td>
<td>Lifting lobby</td>
<td>back, μci, φc</td>
<td>for, μci, φc</td>
<td></td>
</tr>
<tr>
<td>07/L</td>
<td>Elevator entrance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08/C</td>
<td>Placing solid boxes on the ground floor</td>
<td>for, μyi, φc</td>
<td>back, μyi, φc</td>
<td></td>
</tr>
<tr>
<td>09/L</td>
<td>Placing void boxes</td>
<td>back, μci, φc</td>
<td>for, μci, φc</td>
<td></td>
</tr>
<tr>
<td>10/L</td>
<td>Connecting solid boxes with void boxes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/M</td>
<td>Roof garden</td>
<td>back, μyi, φc</td>
<td>for, μyi, φc</td>
<td></td>
</tr>
<tr>
<td>12/M</td>
<td>Strolling circulation</td>
<td>back, μyi, φc</td>
<td>for, μci, φc</td>
<td></td>
</tr>
<tr>
<td>13/C</td>
<td>Bridge across garden</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14/L</td>
<td>Seeing cylinder in the arcade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/C</td>
<td>Infilling water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Therefore, the mechanisms of five types of linkages can be identified in Table 4. In forelinks, two adaptation functions along with different operations to transform input ideas: adaptation (substituting) and combination (adding and deleting). Besides, in backlinks, there are two steps for retrieving ideas: divergent in which alternative ideas are linked, and convergent in which these ideas are selected.

Table 4. Different mechanisms within the five types of linkages

<table>
<thead>
<tr>
<th>Types of linkages</th>
<th>Retrieval</th>
<th>Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>o → o</td>
<td>Forelink between ideas</td>
<td>μci</td>
</tr>
<tr>
<td>o ←→ o</td>
<td>Backlink between ideas</td>
<td>μci, μci</td>
</tr>
<tr>
<td>o ← o</td>
<td>Forelink from cases to ideas</td>
<td>μci</td>
</tr>
<tr>
<td>o →→ o</td>
<td>Backlink from ideas to cases</td>
<td>μci, μci</td>
</tr>
<tr>
<td>o →→ o</td>
<td>Backlink between cases</td>
<td>μci</td>
</tr>
</tbody>
</table>

In addition, designers always used domain concept vocabularies in accompaniment with visual expression (such as sketches, images) to
associate ideas. For example, designer (L) showed the images of the Wang’s house, which stimulated designer (M) to recall another case “House in Brasschaat”. And then he used concept vocabulary “placing void boxes” and idea sketches to express the generated idea. Based on the above cognitive study, a CBR framework to support idea association is proposed.

5. **A COMPUTATIONAL APPROACH**

During brainstorming, idea association involves in an interactive and immediate process for linking memory dynamically. Due to the limitation of short-term memory, Dynamic Idea-Maps (DIM) is proposed to support designers for associating related and meaningful ideas in conjunction with other participants. The components of DIM and its CBR framework are discussed in the following section.

5.1 **Components in DIM**

Based on the above cognitive study, DIM employs the five types of linkages to dynamically link ideas with design precedents. Therefore, DIM can be considered as an idea generator within a graph-like idea structure of nodes and links. The idea structure contains idea entities, three linking constraints, and two interactive processes (retrieval and adaptation).

5.1.1 **Idea entities**

DIM concentrates on generating ideas in the early conceptual design stage. Case representation, more specifically focuses on representing the conceptual knowledge embedded within design precedents. Oxman (1993) decomposes precedent knowledge into separate independent idea entities (called chunks), which provides a potential method for representing cases. Therefore, the basic modules of design precedent knowledge are idea entities, rather than instances of cases.

Basically, an idea entity includes two parts: design problem and its solution. Each solution includes abstract concept and concrete example. Thus, an idea entity composes of three properties: design problem, abstract concept, and concrete example. These properties are organized into a semantic net based on domain concept vocabulary accompanied with multimedia.
5.1.2 Linking constraints

Therefore, any idea entities can be linked by semantically matching any two properties within a design precedent. According to different purpose, DIM has three linking constraints to link idea entities within design precedents: similarity, contrast and contiguity. Each constraint has its individual mechanism to link two specific properties of an idea entity with others. For example, contrast uses two properties (design problem and abstract concept) to match input ideas. The purpose is to link new idea entities with contrast concept and its concrete example.

5.1.3 Retrieval process

In DIM, symbolic values are index values that are textual. Thus, matching any two similar keywords (attributes) embedded within the properties can retrieve idea entities of design precedents. Through the three linking constraints, two steps for retrieving idea entities are involved: divergent in which alternative idea entities are linked, and convergent in which these linked idea entities are selected based on control strategies.

In addition, DIM offers two possibilities for retrieving idea entities: directed search and browsing. While an explicit idea is known, the user can input any two properties of the idea to directly search relevant idea entities. While the user input one property of the idea, he can browse all alternative idea entities within a certain overall boundary.

5.1.4 Adaptation process

There are two functions to adapt idea entities retrieved from design precedents: adaptation and combination. Through linking constraints (similarity and contrast), the attributes of properties within an idea entity are substituted by adaptation. Besides, idea entities are added or deleted by combination through the linking constraint (contiguity). Therefore, adaptation process involves more than quantitative addition (or deletion) of idea entities to the idea structure. There are also qualitative changes in each idea entity.

In addition, dealing with change is an important characteristic of DIM. Idea association involves in dynamic interactions with design situation such as design knowledge, design tasks, and participants. Therefore, DIM allows these idea entities and linkages to be dynamically transformed according to different design situations.
5.2 The CBR framework for DIM

Basically, the CBR framework includes the interface, the idea repository, and several case bases. The interface is an entry for input and output idea entities. The idea repository stores the generated idea entities. And, each case base composes of a case library, a dictionary, and individual reasoning engine (retrieval methods and control strategies). The dictionary analyses keywords embedded within properties of idea entities according to the three constraints of linking (Figure 6).

Within this framework, user can liberally select different case bases for generating ideas. Therefore, these idea entities and linkages will be changed dynamically in the process of idea association.

6. CONCLUSION

This paper provides a basic understanding of the linking process of idea association. During brainstorming, design precedents can be considered as important stimuli for generating ideas. Different types of linkages have their individual mechanisms to link idea entities with design precedents in conjunction with other participants. The idea entities and the linkages form a dynamic idea network, which provides a computational mechanism of idea association.

DIM is a design tool for supporting idea association within the confluence of symbolic representations and semantic content. DIM also
provides a flexible and multi-knowledge design environment. Thus, DIM will be helpful for a creative problem-solving meeting in the task domain of early conceptual design in architecture. Besides, distributed interaction is another crucial issue of idea association. Therefore, integrating DIM with the application of distributed AI (such as agent system) will be investigated in our future research.

ACKNOWLEDGEMENTS

My greatest gratitude and respect are extended to Dr. T.W. Chang, who has offered me guidance and valuable suggestions. I am also thankful to C.Y. Lin, W. S. Lai and J.H. Lin who participated in my experiments. Without their assistance, I would have been unable to complete this paper successfully.

REFERENCE

Kolodner, J. L., 1993, Case-Based Reasoning, Morgan Kaufmann Publishers, Inc. press
Oxman, R. E., 1993, Precedents: Memory Structure in Design Case Libraries, CAAD Futures ’93, p. 273-287