A STUDY IN LINKING INTERACTION FOR SUPPORTING IDEA ASSOCIATION

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Abstract. Idea association is an interactive behavior that will invoke different levels of linking interaction in the conceptual design stage. For understanding the mechanisms of the linking interaction, this research explores the phenomena of linking interactions within idea association during the conceptual design stage. Based on the mechanisms (representation, recall and communication) found from the phenomena, we integrate the mechanisms with the computational technologies (case-based reasoning and software agents). Finally, a preliminary computational mechanism of linking interaction for supporting idea association is proposed.

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*, or the association of ideas, 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 apply the principles of idea association to generate ideas, and then interact with the other participants (Lai, 2005). Idea association can be regarded as the catalyst that triggers the interaction among the participants. By linking the designer's long-term memory internally and the various participants' knowledge externally, diverse design ideas can be generated. Such linking, which involves dynamic interaction in the idea association process, is called *linking interaction*. Due to its reflective reaction, it's hard to understand how the distributed knowledge and information within designers' are linked dynamically in an actual design situation.

There are relevant computational technologies that can be applied into the linking interactions. For linking the information effectively, organizing and representing over these information provides mechanisms for understanding

human dynamic memory computationally. Different reminding mechanisms such as Schank's story-based and goal-based scenarios (Schank, 1999) can access the organized memory/information directly. Based on the analogy between design problems and previous experiences, an approach to reasoning called case-based reasoning (simply called CBR) (Kolodner, 1993) is often considered as a direct implementation of reminding (Maher, et al., 1995; Oxman, 1994; Flemming, 1994). Within the domain of distributed technology, the computing theory of software agents (simply called agents) is brought into implementation consideration for supporting the collaboration of distributed knowledge entities (Ligtenberg, et al.2001; Liu, et al., 2002). As mentioned above, this paper intends to propose a preliminary computational mechanism for supporting idea association by exploring the phenomena of linking interaction and integrating with the computational technologies.

2. Phenomena of Linking Interaction within Idea Association in the Conceptual Design Stage

Idea association is a behavior by which one idea leads to another by a linking made in the long-term memory (Osborn, 1963). The technique of linking is originally attributed to the Ancient Greeks, even Aristotle. Additionally, the Ancient Greeks organized the linking of diverse ideas into three principles: *similarity*, *contrast* and *contiguity*. During a design process, a designer applies the principles to link his long-term memory internally as well as participants' knowledge externally. According to our pilot studies (Lai, 2005; Lai, et al., 2005), there are three kinds of phenomena of linking interaction in the conceptual design stage. These phenomena are described in the following sections.

2.1. USING DESIGN CASES TO GENERATE IDEAS

An idea is considered as a solution for solving a specific problem within a given task. For solving the problems, there is a tendency to use design cases as references and to extract past experiences to generate ideas. 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. With this approach, linking interaction can be treated as a mechanism of searching for relevant ideas among design cases.

Designers 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. They are also used to applying a domain's conceptual vocabulary as symbols to represent these attributes and elements within the design context, and construct their relationships accordingly. These ideas and their relationships mostly contribute to a designer's long-term memory. By applying different media (such as sketches, text, keywords or photo-images), an idea can be effectively represented from different points of view.

2.2. USING THREE PRINCIPLES OF IDEA ASSOCIATION TO REMIND MEMORY

The three principles mentioned before provide the effective linking strategies to remind the designer's long-term memory. 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 link 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, contrasting conceptual vocabulary can be used to link contrasting design ideas, such as public and private, solid and void, linear and center, etc. Consequently, these three principles embody the different relationships among the design ideas.

2.3. USING ROLE-PLAYING TO EXCHANGE INFORMATION AMONG PARTICIPANTS

Idea association involves two levels of interactions where participants act and re-act internal and external knowledge through a dynamic linking process. In the linking process, participants always play the different roles and then employ the different principles described above to link and generate diverse ideas. Within the internal interaction, each participant plays different roles and uses different design knowledge 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 within the external interaction. This interaction also directly encourages the designer to play different roles and use different design knowledge to link their ideas. The two interactions follow a sequentially ordered process for exchanging information (Figure 1).

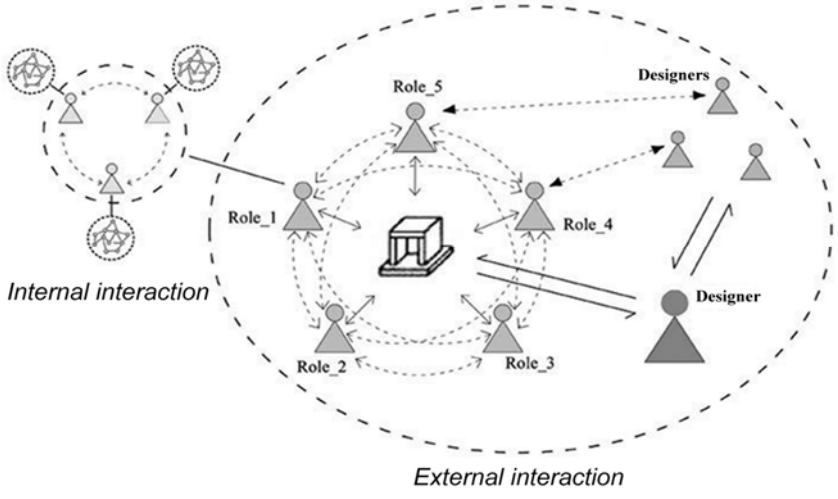

Figure 1. Two levels of interactions: internal and external

2.4. THREE MECHANISMS OF LINKING INTERACTION

While ideas derive from design cases, the *representation* of design cases is the primary mechanism that should be considered. For reminding the designer's long-term memory and exchanging information embedded with other participants', *recall* and *communication* are the other mechanisms of linking interaction. Therefore, the linking interaction within idea association composes of three mechanisms: representation, recall and communication. The relationship can be formulated as follows:

Representation + Recall + Communication = Linking interaction (1)

Representation is related to the methods of representing design cases, ideas and their linking relationships, and organizing memory. Recall provides reasoning rules and constrains to remind designers' memory through the three principles of idea association. Communication supports the process of exchanging information to link ideas in a distributed design environment.

3. Integrating with the Computational Technologies

In the computational domain, CBR is a research paradigm that uses design cases for solving a new problem based on previous design experience by analogical reasoning (Kolodner, 1993). Representation and recall are the two important computational mechanisms of CBR to access case bases directly. Agents are autonomous and reactive entities that have communicative capabilities to interact with dynamic situations (Wooldridge and Jennings, 1995). These lead to our approach: integrating with the CBR and agent technologies to approach a computational mechanism of linking interaction for supporting idea association.

3.1. INTERGRATING WITH THE TECHNOLOGY OF CBR

In CBR, design cases are considered as condensed knowledge of previous design experience that provides design solutions for problem solving. For representing design cases, design cases are decomposed into diverse knowledge chunks and organized relatively in different computational ways. The computational ways need to respond to the purpose of the given design task. For recalling the knowledge of design cases, the optimal design cases are searched effectively through a reasoning process (including index, retrieval and selection). The mechanisms within CBR can be integrated with the representation and recall of linking interaction.

3.2. INTERGRATING WITH THE TECHNOLOGY OF AGENTS

Agents can be thought of as a distributed computational technology. A design task is decomposed to different sub-tasks that are assigned to different agents. With autonomous, reactive, and communicative behaviors, agents can autonomously participate in role-playing to interact with the internal and external design situations. Through the mechanism of Agent

Communication Language (simply called ACL) and agent organization, agents as well as human designers can play different roles, and then apply different principles to link design ideas. In addition, the mechanism of ACL supports different network topologies of exchanging information in the process of role-playing (Figure 2).

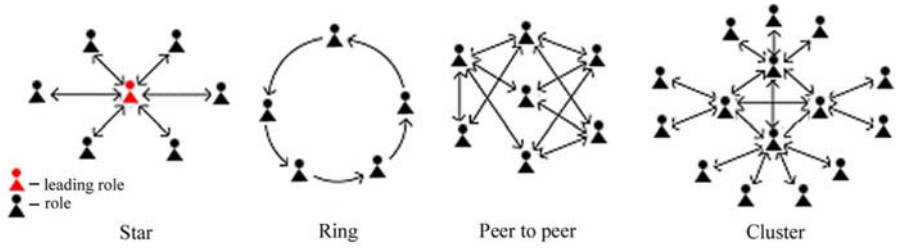

Figure 2. Four network topologies: star, ring, peer to peer and cluster

4. A Computational Mechanism of Linking Interaction for Supporting Idea Association

The computational mechanism of linking interaction is proposed to support two or more participants for associating ideas in the distributed design environment. The computational mechanism includes different kinds of *agent entities* (called roles). Each role assigns to different sub-tasks that are decomposed from a specific design task. According to different design situations, these roles collaborate to link and generate design ideas. For supporting the collaboration, these roles have the *linking knowledge* to interact with each other. The linking knowledge composes of representation, recall and communication. The agent entities and linking knowledge construct the computational mechanism of linking interaction (Figure 3).

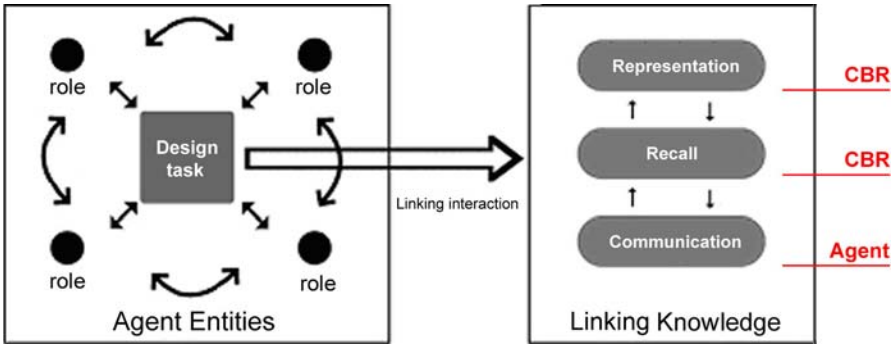

Figure 3. The computational mechanism of linking interaction

Representation supports related knowledge representation (KR) and memory organization between ideas, cases and their relationships, which are stored in the case memory of a role. Recall provides each role to apply different principles of idea association to reflectively remind its case memory to generate diverse and related ideas. The principles (similarity,

contrast and contiguity) have their individual reasoning rules and constrains for indexing, retrieving and selecting design cases. For dynamically interacting with other roles, communication allows the role to exchange information (sending and receiving message) through the mechanisms of ACL according to different design situations. The roles will evolve their linking knowledge through their competition in the role-playing process. Moreover, the design outcomes and linking process will be presented immediately through a visualized interface.

5. Conclusion

Idea association is an interactive behavior that invokes different levels of linking interaction in the conceptual design stage. Through this research, three important mechanisms of linking interaction within idea association are representation, recall and communication. The three mechanisms are integrated with the computational technologies of CBR and agents. Representation is related to a role's (or an agent entity) knowledge representation and memory organization of design cases. Recall provides different reasoning rules and constrains to remind the role's case memory dynamically. Communication establishes the policy to control the process of exchanging information among roles.

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 generate diverse and related design ideas without the barriers of geographic limitations and different time zones.

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