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A computational cognitive model of user applying creativity technique in creativity support systems

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Abstract

Numerous creativity techniques have been purposed and applied in creativity support system. Because most creativity techniques are used informally and hardly represented formally in computer, it becomes very difficult to build the computational cognitive model of user applying those techniques. However the model is necessary for creativity support systems to detect or predict the change of user's cognitive state in time and make some adaption to avoid inhibiting creativity of user. In this paper we introduce extension creative idea generation method which has the characteristics of formalization and systematization. The method can be represented by extension rules which provide the precondition to build computational cognitive model of user in creativity support systems. The computational cognitive model of user learning in applying extension creative idea generation method is presented through experiments. The experimental results show how and when the user will develop the application skill of creativity technique and inhibit his creativity.

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Keywords: Creativity support systems; Creativity technique; Extension creative idea generation method; Computational cognitive model;

1. Introduction

Boden considered that creativity can be defined as the ability to generate novel, and valuable, ideas [4]. For supporting people to generate creative ideas more and better, numerous creativity techniques such as the brainstorming technique [30], TRIZ [1] have been proposed. Forster and Brocco said that "literally hundreds of creativity techniques were proposed and researched, providing findings that most of them can improve creative problem solving" [13]. Naturally those techniques have been applied in creativity support systems however there are still many difficulties to overcome. One of the difficulties is that most techniques are still lack of compelling theoretical and causal foundations [31]. Some researchers have noticed this and purposed the new creativity techniques and models [31-32].

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Creativity techniques need a theoretical foundation of cognitive science to explain their effectiveness, for idea generation is a kind of cognitive activity of individuals. On the other hand, obviously the users of creativity support systems have cognitive abilities such as memory and learning. The abilities have a certain degree of influence on the users applying creativity techniques and generating ideas in the systems. For creativity support systems, not only the creativity techniques are need to help users generate ideas, but also the computational cognitive model of user is necessary to comprehend how the user come up with the new ideas, and detect or predict the change of their cognitive state. Such comprehension, detection or prediction is necessary for the system to make some adaption in time and maintain the vitality of user's creativity. However existing creativity techniques seldom consider how the cognitive factors, e.g. memory, learning, attention, etc. have effect on creativity. Moreover most creativity techniques are used informally and hardly represented in computer. As a result, it becomes very difficult to build the computational cognitive model of user applying creativity technique in creativity support systems.

In this paper a novel creativity technique, extension creative idea generation method is introduced. Different from other creativity techniques, the method is built on the basic of Extenics, a mature theoretical framework for solving contradictory problems creatively. Therefore the method has more competitive advantages for applying in creativity support system. And more importantly, extension creative idea generation method can be represented formally by extension rules, which provides the precondition to build computational cognitive model of user in creativity support systems. We build a computational cognitive model of user learning in applying extension creative idea generation method in creativity support systems. The experimental results of the model show how and when the users learning in applying the extension rules.

2. Extension creative idea generation method

2.1. Extenics and creative problem solving

Most theories of problem solving have focused on explicit processes that gradually bring the problem solver closer to the solution in a deliberative way [15]. However for the ill-defined or complex problems, the solver needs to generate some creative ideas for the "change of perspective" [18], rather than only searching the solutions in a given problem space. Creative problem solving studies people how to solve such ill-defined or complex problems. Creativity support system can be the useful tool by helping the user to represent the problems and produce ideas.

Some computational models of creative problem solving have been proposed [12, 15-17, 19]. Few of existing computational models of creative problem solving can be directly applied in creativity support systems, for most of them mainly focus on how to simulate creative idea generation. However, the creative process of problem solving includes not only idea generation, but also problem presentation and preparation, idea evaluation and selection, etc. [14]. How to combine those computational models and the models of creative process [25] for designing creativity support systems is still lack of systematize theories and methods.

Extenics is a new cross discipline which "studies the possibility of extending things, rules and methods of developing innovation with formalized patterns, and is used to resolve contradictory problems" [6, 8, 33, 34]. In recent years, interdisciplinary research between Extenics and data mining [22, 35], knowledge management [23] is developing rapidly. Based on Extenics, a collaborative innovation model in the context of big data is given in [24].

For creative problem solving, Extenics provides the systematic method called extension innovation method to help people "to complete the process of 'discover problems → establish models of problems → analyze problems → generate strategies for solving problems' with formalized models" [34]. In other words, Extenics provides a theoretical framework of creative problem solving which can be easily deployed in the creativity support systems.

2.2. Extension rules and idea generation

Extension theory introduces the concept of basic-element to represent information. A basic-element can be expressed by $B = (O, c, v)$ where O represents object, c is the characteristic of O, and v is the measure of O about c. If we consider idea as the mental representational images of some objects, we can say that idea can be just represented by some basic-elements or their combinations. As a result, the concept of idea generation in Extenics can be defined as the production of some basic-elements from the given basic-elements.

Idea generation is a key step in creative problem solving. Many creativity techniques were purposed but lack of the proper and formal representation, few of them have a reliable theoretical foundation of problem solving. In Extenics the creativity technique of idea generation is called extension creative idea generation method [34]. Different from other existing creativity techniques which is hardly formalized, extension creative idea generation method can be represented through a set of extension rules [7, 36].

In Extenics extension rules include extended rules, conjugate rules, conductive rules, and logical calculus rules of basic-elements and operational rules of transformations [36]. We take the divergent rules belonging to extended rules as example. Assume that $£(c)$ is the set of all characteristics, "$B_1 \dashv B_2$" expresses "basic-element B_2 can be diverged through basic-element B_1". Some divergent rules are given as follows:

Divergent rule R_1: $B \dashv \{B_i \mid B_i = (O, c_i, v_i), i=1, 2,\ldots, n, c_i \in £(c)\}$

Divergent rule R_2: $B \dashv \{B_i \mid B_i = (O, c_i, v), i=1, 2,\ldots, n, c_i \in £(c)\}$

Divergent rule R_3: $B \dashv \{B_i \mid B_i = (O_i, c, v_i), i=1, 2,\ldots, n\}$

Divergent rule R_4: $B \dashv \{B_i \mid B_i = (O_i, c, v), i=1, 2,\ldots, n\}$

With the conduct of creativity support systems, the user can choose some extension rules to generate creative ideas, that is, the user can get the new idea B_i from B by applying, for example, the divergent rules. With the application of extension rules, the system is not just a dynamic electronic blackboard [9], it provides a framework to organize the user's thoughts, and even it can automatically generate the new ideas by extension reasoning [7]. On the other hand, because the thinking process of users is conducted by the application process of extension rules in creativity support systems, it become possible to detect or predict the change of user's cognitive state through simulation by the computational cognitive model of user.

3. Computational cognitive model

3.1. Memory-based models of idea generation

In this paper, we mainly focus on the memory-based models for creativity cannot occur without the participation of memory processes and structures [26]. Memory-based models of idea generation consider idea generation as a memory-based cognitive activity, "committing to the principle that ideas are produced by retrieving information from a permanent, associatively organized long-term memory system and processing it further" [20]. According to the existing research works, there are several memory-based models of idea generation, including the matrix model [5, 11], SIAM (Search for Ideas in Associative Memory) model [28-29] and its extended model for design [20], etc.

Based on the above viewpoint, the value of extension creative idea generation method is that it provides memory-search strategies for user constructing different cues that help to solve problems. Thus we can build a memory-based model of users who apply extension creative idea generation method in creativity support systems.

Furthermore, when the user applies some creativity techniques to generate ideas, not only the related chunks in memory will be activated, but also he can learn some procedural knowledge about application of techniques. Procedural knowledge learning of user has special significant for creativity support system, because the system can get to know the user's master level of certain technique application instance, thus making some timely adaption to avoid stifling the user's creativity.

In cognitive science, human individual learning procedural knowledge is called skill acquisition. For developing cognitive model of skill acquisition, knowledge compilation theory [2] and chunking theory [27] were proposed. Lee and Taatgen incorporated aspects of both Anderson's and Newell and Rosenbloom's account, proposing production composition theory [21]. Production composition eliminates the retrieval process and creates a single rule out of the two original rules while substituting the retrieval into this new rule. Through this process, general rules can be specialized into task-specific rules [21]. In this paper we built the model of skill acquisition based on production composition theory.

3.2. Experiments

We built the computational cognitive model on the basic of cognitive architecture ACT-R [3]. The model can simulate the change of user's cognitive state, including the state of memory and learning when it get stimulations and apply some extension rules as memory-search strategies to retrieve information in memory. According to production composition theory, our model will acquire procedural knowledge when repeatedly applying the instances of extension rules. As limited by space, only the experimental results of model learning are presented here. The model of information storage and retrieval in memory is discussed in [10]. The experiments presented here mainly aim to show that how our model simulated the user acquiring skills when they apply extension creative idea generation method as creativity technique.

Table 1. Basic-elements of experiments

NO.	Content
B_1	(person A, nationality, France)
B_2	(person A, residence, France)
B_3	(person B, gender, male)
B_4	(person B, profession, lawyer)
B_5	(person C, gender, male)
B_6	(person C, profession, fireman)
B_a	(person B, hobby, exercise)
B_b	(person A, birthplace, France)
B_c	(person B, profession, teacher)
B_d	(person A, gender, male)

Table 2. Results of experiments

NO.	Application of winning rule	Application count of rules			
		R_1	R_2	R_3	R_4
1	$B_a \dashv B_3, B_4$	17	1	1	1
2	$B_b \dashv B_1, B_2$	0	15	1	1
3	$B_c \dashv B_4, B_6$	1	1	17	1
4	$B_d \dashv B_3, B_5$	0	0	0	17

In every experiment the stimulations were presented to the model in the form of basic-element. The model simulated the process of user applying four divergent rules given in section 2.2 and retrieved information in long-term memory. We used the form of basic-element to represent the retrieval results. The related basic-elements in the experiments are presented in table 1. The results of four experiments are listed in table 2. In every experiments, there are several rules can be applied but the model will only choose one as winning rule. In each execution of the same experiment the model received the same stimulation.

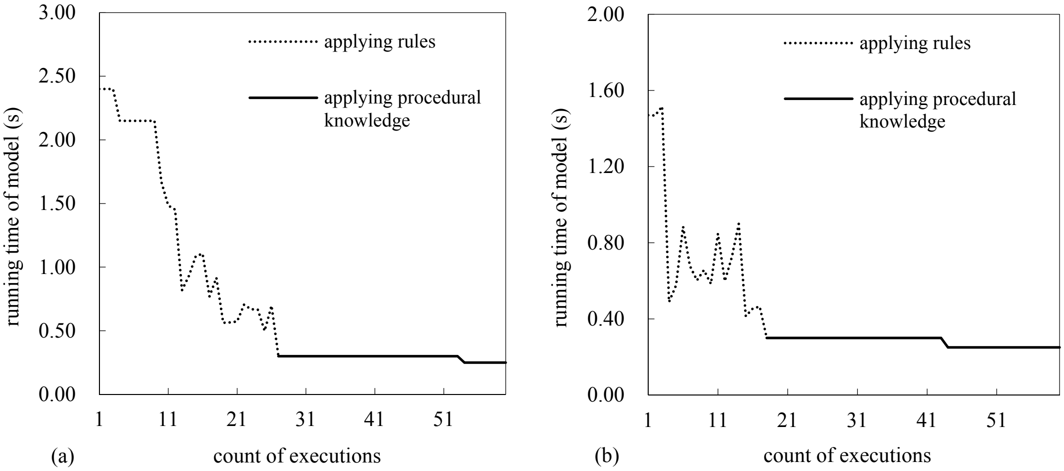

Fig. 1 model learning process of (a) experiment 1; (b) experiment 4

The model learning process in experiment 1 and 4 are presented in figure 1. The figure shows that after acquiring the procedural knowledge the model speeded up through replacing the application of the extension rules by the application of procedural knowledge. However, in the later time of the experiment, the model only used the procedural knowledge that it has learned and the extension rules are not applied any longer. Meanwhile as we can see in table 2, because of the learning mechanism the model usually prefers to select the winning rule to apply repeatedly and seldom try other rules.

4. Discussion

As a tool for users to generate ideas and solve problems, creativity support systems should have the ability to breaking the inertia of user's thinking. However, once the system provides some techniques to conduct user's thought, inevitably the users may slide into mechanical habits of thought when they encounter the same or similar situation. An important cognitive factor behind this is the tendency of user's skill learning. In this paper, we discuss the problems of existing creativity techniques applied in creativity support systems, and introduce extension creative idea generation method. With the feature of formalization and systematization, extension creative idea generation method provides not only a useful creativity technique for creativity support system to conduct users generating ideas, but also the possibility for building computational cognitive model of user. We built the computational cognitive model to simulate user learning in applying creativity technique. The experiment results show how and when the user will develop the application skill of creativity technique and inhibit his creativity. Based on our model, creativity support systems can detect or predict the change of user's cognitive state in time and make some adaption, thus playing a real role in supporting creativity of users.

In this paper we assume that users apply creativity techniques in individual creativity support systems. Further our work needs to be expanded to the field of group and organizational creative support systems. In the future, we will study how other cognitive factors such as attention, reasoning affect creativity of users and how creativity support systems can take advantage of those influences and eliminate its disadvantages.

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