"What" and "Where" is design creativity: a cognitive model for the emergence of creative design

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Abstract
This paper attempts to propose a broader framework for understanding creativity by distinguishing different levels of creativity, namely personal and social/cultural creativity, and their interaction. Within this framework, the possible role that the computer can play is discussed by analyzing the procedure of rule formation and the phenomena of seeing emergent subshapes.

1 Introduction

In the 1950s, Simon and his associates described creative behaviour as a peculiar search and implemented this view using a computer program (Newell, Shaw and Simon 1962). On the other hand, creativity has also been examined within a social/cultural framework (Csikszentmihalyi 1986; 1988). In some sense, the two views regarding the same enterprise, creativity, are conflicting. In this paper, I attempt to come up with a broader framework for understanding creativity by distinguishing different levels of creativity, namely personal and social/cultural creativity, and their interaction. Within this framework, the possible role that the computer can play is discussed. Moreover, given this framework, the emergence of subshapes (Mitchell 1993; Stiny 1993; Liu 1993, 1994, 1995, 1996, in press; Gero and Yan 1993; Gero 1995) in relation to the emergence of creativity becomes clearer.

2 Kinds of Creativity

Creativity is still one of the most mysterious subjects in human cognition. Academically, researchers have applied many fields to the study of creativity, including the psychometric, cognitive, biological, and social/cultural approaches (Sternberg 1988; Health 1993; Gero and Maher 1993). As stated above, the major gap between Simon's and Csikszentmihalyi's approaches to creativity is that they address different scopes of creativity. Simon focused on the personal level, whereas Csikszentmihalyi pays much more attention to the social/cultural level of creativity. Therefore, while Simon tried to answer "what is creativity," Csikszentmihalyi seems more interested in addressing the question of "where is creativity." To be able to compare the conflicting perspectives on creativity offered by Simon and Csikszentmihalyi, this paper begins by reviewing Simon's observations and computer implementation on creativity.

2.1 Personal creativity: Simon's observations about creativity

In an attempt to answer the fundamental question what mechanism is involved in human creative acts, Simon and his associates (Newell, Shaw and Simon 1962) hypothesised, at first, that it is "a special kind of problem solving behaviour." They then sketched the satisfying conditions for problem-solving of this sort, to be called creativity:

- the product of thinking has novelty and value for the thinker or his culture;
- the thinking is unconventional;
- it requires high motivation and persistence; and
- the problem as initially posed was ill-defined, so that part of the task was to formulate the problem itself (Newell, Shaw and Simon 1962).

Simon and his colleagues simulated scientific discoveries in the computer programs Logic Theorist (Newell, Shaw and Simon 1962) and BACON (Langley et al. 1987), and found that when the correct heuristics and initial data are available, those programs successfully induced Whitehead and Russell's Principia Mathematica, Newton's law, Kepler's third law, Galileo's law, and Ohm's law. The given heuristics, in the form of IF-THEN rules, play critical role in both computer systems. It is fair to say, at least for Simon, that those discoveries were achieved when the scientists applied sensible and critical heuristics in drawing inferences from given data.

With respect to problem formulation and originality, Simon admitted that those computer programs relied on programmers to provide significant problems and simply solve the given problems (Newell, Shaw and Simon 1962, p 147). In sum, according to Simon's theory, human creativity is a specific class of ill-defined problem-solving characterised by novelty, unconventionality, persistence, and difficulty in problem formulation.

2.2 Social/cultural creativity: Csikszentmihalyi's differing view

In his paper on motivation and creativity, Csikszentmihalyi (1986; 1988) strongly criticised Simon's idea of creativity and those computer programs. His argument has three points:

- According to Einstein and Infeld's (1938) insight about scientific discovery, the critical issue of creativity is problem-finding, not problem-solving.
- According to Getzels' (1964) definition of discovered problem-solving, the problem, the method, and the correct solution are all unknown.
- Recognising the solution and proving it to others are the most difficult parts in creativity.

Almost utterly denying Simon's ideas and programs on creativity based on the above viewpoints, Csikszentmihalyi instead came up with a dynamic framework of creativity composed of three major elements—person, field, and domain—as shown in Figure 1 (Csikszentmihalyi 1988).

> This 'map' shows the interrelations of the three systems that jointly determine the occurrence of a creative idea, object, or action. The individual takes some information provided by the culture and transform it, and if the change is deemed valuable by society, it will be included in the domain, thus providing a new starting point for the next generation of persons. The actions of all three systems are necessary for creativity to occur (Csikszentmihalyi (1988, pp. 329).

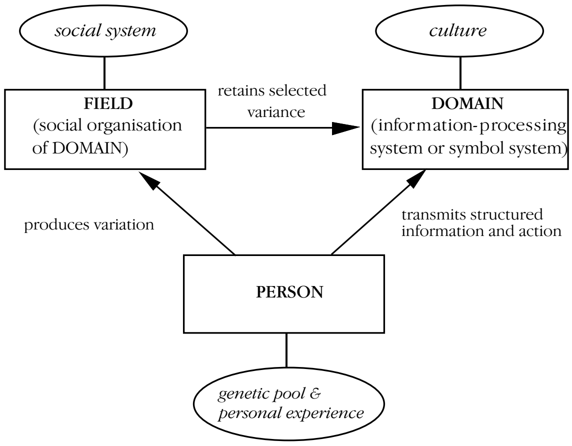

Figure 1: A dynamic framework of creativity (after Csikszentmihalyi 1988)

Within the 'person' element, Csikszentmihalyi (1986, 1988) broadly but very abstractly mentioned that motivational, affective, cognitive and demographic variables and early experience are key issues to use when examining human creative behaviour.

3 Re-examining Creativity

Both models provided by Simon and Csikszentmihalyi seem to capture some of the essence of creativity, however there is still some ambiguity when people interpret Simon's creativity as a problem-solving. Before discussing the distinctions between Simon and Csikszentmihalyi and trying to integrate the two views, the critical points are what is an ill-defined problem by Simon's definition and how to solve it.

The characterisation of an ill-defined problem is:

- there is no definite criterion to test a proposed solution;
- the problem space is not defined, in other words, the boundaries of the relevant information are vague; and
- there are no legal moves (Simon 1973, 1978).

To solve ill-defined problems, the problem-solver should decompose the entire problem into well-defined sub-problems and solve them individually. The means-ends analysis is a typical mechanism for solving ill-defined problems.

3.1 Problem-finding, not problem-solving

Simon did take problem-finding into account in his theory and also in 'Logic Theorist' and 'BACON'. He claimed that

> perhaps the real creativity lies in the problem selection. . .Logic Theorist has some power of problem selection. In working backward from the goal of proving one theorem, it can conjecture new theorems—or supposed theorems—and set up the subgoal of proving these. (Newell, Shaw and Simon 1962, p 147).

The problem selection process in Logic Theorist and BACON is quite different from Csikszentmihalyi's definition of problem-finding. For instance, in discovering Newton's law, what Csikszentmihalyi expects BACON to do is to find the initial problem of universal gravitation by observing an apple falling. Unfortunately, BACON is only able to find other problems or subproblems, although Simon did emphasise the initial problem-finding.

3.2 The problem, the method, and the correct solution are all unknown

Csikszentmihalyi (1986, p. 4) mentioned that when

> Newton solved the problem of universal gravitation, in most important respect, that law did not exist to be solved before he discovered it.

Consequently he argued that, in BACON's discovery processes, the initial problem, the correct heuristics, and the solution are all known in advance. It is no longer creative. This reminds me of Marvin Minsky's joke about creativity: when creative people simply show us the outcome, we can view it as creative; if we observe both the process of doing it and the outcome, the creativity is gone. This raises the important question of how we know that, before he discovered universal gravitation, Newton did not know the problem, the method, or the solution. Probably when he observed the apple fall, he began to find the problem regarding it. After a long time thinking, maybe he discovered a concrete problem to be solved. Having solved that concrete problem which was only in his mind, not in ours, Newton in turn began to find a correct method or heuristics. After a long period of time spent finding, he obtained some necessary heuristics. Eventually he solved the problem by applying those heuristics to the given data.

Perhaps I imagine too much. Perhaps I am right. It seems to me that creativity is a huge ill-defined problem which, using Simon's approach, can be decomposed into problem-finding, heuristics-finding and solution-finding. The computer programs Logic Theorist and BACON contribute to modelling the third phase in the process of creativity once the subproblems in the first two phases are solved. How to find the concrete problem and how to find the necessary heuristic rules are two more, separate problem-solving processes.

3.3 Recognising the solution and proving it to others

That we cannot recognise its solution is one typical characteristic of the ill-defined problem, as mentioned previously. As Simon (1973) says, for ill-defined problems, the human problem-solver looks for one of the satisfying solutions rather than the optimal one.

There are two levels for recognising the solution: personal recognition by the creative person and cultural recognition by other people. The proposed solution can become creative only when, first, the person recognises it as satisfying solution and, second, he proves it to the world and the world accepts it and then recognises it as creative.

The first part of the solution recognition can be achieved more easily by computer. If a proposal solution can satisfy the constraints and clearly explain the phenomena of the given problem, and is original, it can be recognised as a good and novel solution. The second part of the solution recognition is very difficult by computer. But, from my point of view, it is not the computer's responsibility but that of culture and society.

4 Remodelling Creativity

Based on the above discussion and Simon's theory, creativity is not simply either a matter of problem-solving or an ill-defined case of problem-solving. Instead, it is a special and huge ill-defined problem-solving behaviour, not only composed of problem-finding, heuristics-finding and solution-finding and recognition, but also characterised by motivation, originality and unconventionality. Does this mean Simon's theory is complete? Of course not. From the above discussion, a person or a computer can propose a solution and recognise it as a satisfying one. Without others' proper recognition, that solution is simply treated as novelty not creativity. Another weakness is the question of where the given data comes from.

Csikszentmihalyi's (1988) framework of creativity can fill these slots. He successfully models an outer framework for creativity but lacks the inner processes for the three elements, namely person, field and domain. On the other hand, Simon's theory saliently reveals the cognitive processes of creative behaviour, the inner system of the person, but lacks an explanation for the whole contextual framework in terms of culture and society. Each can help the other. It is widely agreed that creative activity includes motivation, persistence, originality and variation (Newell, Shaw and Simon 1962; Simon 1966; Csikszentmihalyi's 1988; Gardner 1988, 1993; Hayes 1989; Perkins 1981; Hofstadter 1985; Minsky 1985). In a broader sense, they are important parts of the method or heuristic for problem-solving. I would like to treat them as domain-general heuristics, that is trying something new and trying harder. They are required for the emergence of creativity in any domain. What is needed is to find domain-specific heuristics.

4.1 The framework: a dual generate-and-test model of creativity

It seems to me that, although they both address issues about creative activities, Simon and Csikszentmihalyi do not share the same focus: Simon pays more attention to personal aspects of creativity, while Csikszentmihalyi is more concerned with its social/cultural scope. The distinction between the personal and social/cultural levels of creativity reminds me of the terms "small-c" and "big-c" creativity used by Gardner (1992): many people are (small-c) creative for themselves, but only a few of them might be recognised as (big-c) Creative socially and culturally. For example, every architect pursues creative works. First, on the personal level, they must try a great number of alternatives and finally come up with a creative solution for themselves. Next, on the social/cultural level, they must seek national or international recognition of creativity by constructing the building, publishing the work, or even giving lectures and writing books on the theme. For both personal and social/cultural levels, creativity "is a patient search" (Le Corbusier 1960).

Within the personal level, initially, the person has to find a specific problem to explore and solve. Using a generate-and-test scheme, the creator must then go through a cyclic process of creativity generations and tests until the proposed solution passes the personal test and becomes the creative solution for him. Note that the sources of initial data and knowledge in the domain, at this level, provide necessary support for personal creative activity, but they are stable. The new, creative idea cannot be put into the body of domain knowledge in the mean time because it is only in the person's mind. To be socially/culturally creative, he should show the personal creativity he seeks to the field after he has gone through the personal creativity generate-and-test procedures, as shown in Figure 2.

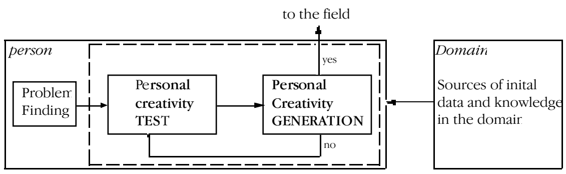

Figure2: A model of personal creativity

Seeking recognition from a group of authorised people makes the person a generator of social/cultural creativity. If the personal creative solution can pass the social/cultural creativity test by the field, it becomes well-known creativity and can be added into the body of human knowledge in the domain; otherwise the person must repeat the personal creativity generate-and-test procedures for another personally creative alternative to be tested by the field. Also note that the source of initial data and knowledge of the domain is no longer stable; it dynamically interacts with the other two social/ cultural components and it grows over time, as shown in Figure 3.

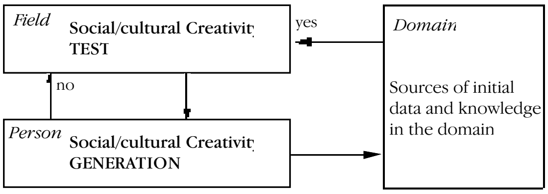

Figure 3: A model of social/cultural creativity

Based on the preceding discussion of personal and social/cultural creativity, a better-defined framework of creativity should subsume these two levels of activities characterised by the person, the field, and the domain. Therefore, a dual generate-and-test model of creativity is diagrammed as illustrated in Figure 4.

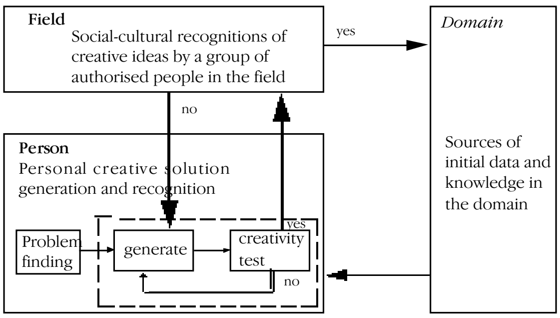

Figure 4: The Framework- A dual generate-and-test model of creativity

5 Conclusion: Implications for CAAD systems

From the implications of Simon's research, people can subjectively pursue personal creative behaviour which can also possibly be replicated by a computer system that has incorporated some initial data and heuristic function towards creativity. At this personal level of creativity, novelty and other choices can be acquired from both knowledge transforming search and shape restructuring search. On the other hand, from the implication of Csikszentmihalyi's research, the emergence of creativity is also a social/cultural activity within which a computer system can hardly participate.

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