A DUAL GENERATE-AND-TEST MODEL FOR DESIGN CREATIVITY

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Abstract. This paper proposes 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 could be further explored by analyzing the procedure of rule formation and the phenomena of seeing emergent subshapes.

1. Introduction

Design creativity is critical to successful computer-aided design systems but there are differences of view about how such creativity can best be understood. In the 1950s, Simon and his associates described creative behavior as a particular 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 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 design shapes (Stiny 1980; Mitchell 1990, 1993; Liu 1993, 1994, 1995, 1996; Gero 1995) in relation to the emergence of creativity becomes clearer.

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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, social/cultural approaches (Health 1993), as well as the computational approach (Gero and Maher 1993; Mitchell 1993; Schmitt 1994) and its implication in design education (Schodek 1994). As stated above, the major gap between Simon's and Csikszentmihalyi's approaches to creativity is that they address different perspectives 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 the implementation by computer 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) hypothesized, at first, that it is "a special kind of problem solving behavior." They then described the satisfying conditions for problem-solving of this sort, to be called creativity:

1. the product of thinking has novelty and value for the thinker or his culture;
2. the thinking is unconventional;
3. it requires high motivation and persistence; and
4. the problem as initially posed was ill-defined, so that part of the task was to formulate the problem itself (Newell, Shaw & 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 a 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 characterized by novelty, unconventionality, persistence, and difficulty in problem formulation.

2.2. SOCIAL/CULTURAL CREATIVITY: CSIKSZENTMIHALYI'S VIEW

As mentioned previously, the complexity and sophistication of human creativity could be understood more appropriately and completely only when we investigate it from more than one perspective. Any study of creativity based on a single perspective would be limited both in view and in its explanatory power. For example, Simon's definition of creativity in terms of problem ill-definedness, heuristic problem-solving, and problem formation can hardly explain why Sandro Botticelli was regarded as one of the great masters in the period of Renaissance only until centuries later when John Ruskin had recognized his work as creative. If we consider another example, we can see the deficit of this kind of single-perspective approach even more clearly. When we look at the Chinese painting shown in Figure 1, we would probably raise a question immediately: whether it is a good or even a creative piece of work? The answer to this question is a yes; the painting is regarded as one of the most creative and important works in Chinese art history. It would be more likely for those with Chinese cultural background to be able to analyze it, interpret it, and further appreciate it. For those without any Chinese background, however, it would be almost impossible for them to do the same. These two examples reveal that an approach which focuses merely on the personal level such as Simon's fails to capture the historical and socio-cultural aspects of creativity. An approach that also takes into consideration these aspects of creativity is thus called for to fill in the gap.

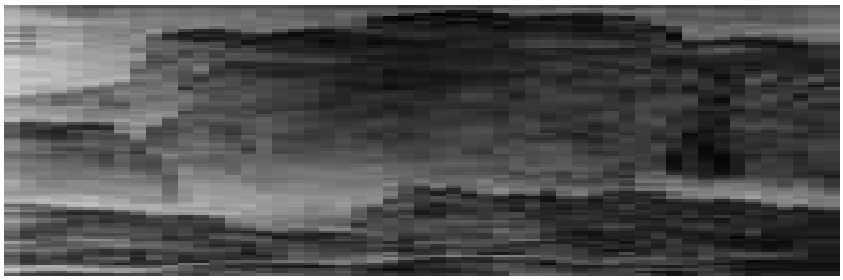

Figure 1. A variant of Travelers on a Mountain Path (Hsi-San), Fan-Kuan, 1000 A.D.

In his paper on motivation and creativity, Csikszentmihalyi (1988) strongly

criticized Simon's idea of creativity and those computer programs. His argument has three points:

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

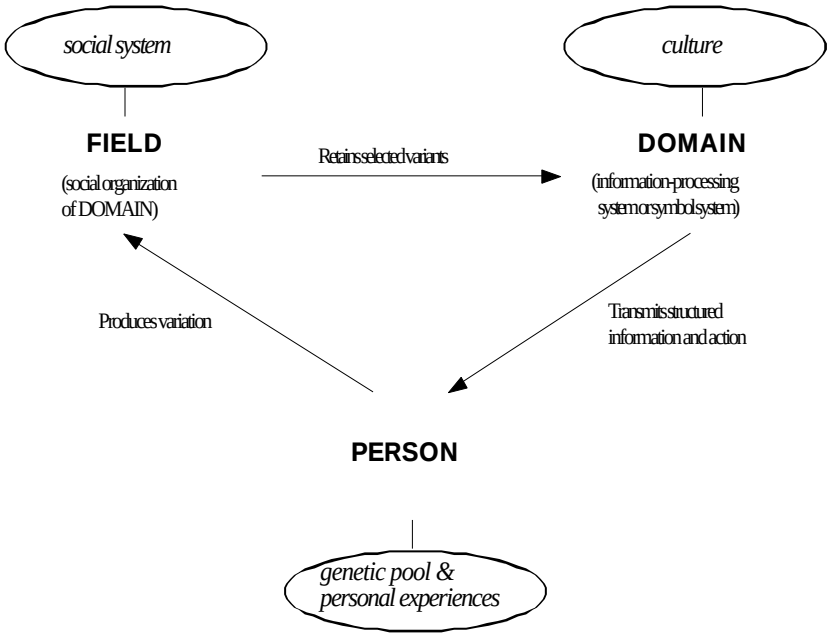

Figure 2. A dynamic framework of creativity (after Csikszentmihalyi 1988)

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 2 (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 transforms 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, p.329)". Within the "person" element, Csikszentmihalyi (1988) broadly but very abstractly mentioned that motivational, affective, cognitive and demographic variables and early experience are key issues to use in examining human creative behavior.

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 problem-solving. Before discussing the distinctions between Simon and Csikszentmihalyi's views 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 characterization of an ill-defined problem is:

1. there is no definite criterion to test a proposed solution;
2. the problem space is not defined, in other words, the boundaries of the relevant information are vague; and
3. there are no explicit rules of knowledge (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 designing *Logic Theorist* and *BACON*. He claimed that "perhaps the real creativity lies in the problem selection. . . *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 the fall of an apple. Unfortunately *BACON* is only able to find other problems or subproblems, although Simon did emphasize the initial problem-finding.

3.2. THE PROBLEM, METHOD, AND CORRECT SOLUTION

Csikszentmihalyi (1988) 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 got some necessary heuristics. Eventually he solved the problem by applying those heuristics to the given data.

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 modeling 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. RECOGNIZING THE SOLUTION AND PROVING IT TO OTHERS

That we cannot recognize 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 recognizing of 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 recognizes it as satisfying solution and, second, he proves it to the world and the world accepts it and then recognizes 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 recognized 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: 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 (1993): many people are (small-c) creative for themselves, but only a few of them might be recognized 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 3.

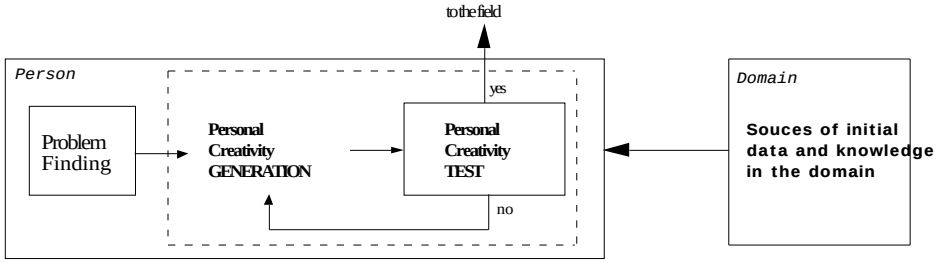

Figure 3. A model of personal creativity.

Seeking recognition from a group of authorized 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 4.

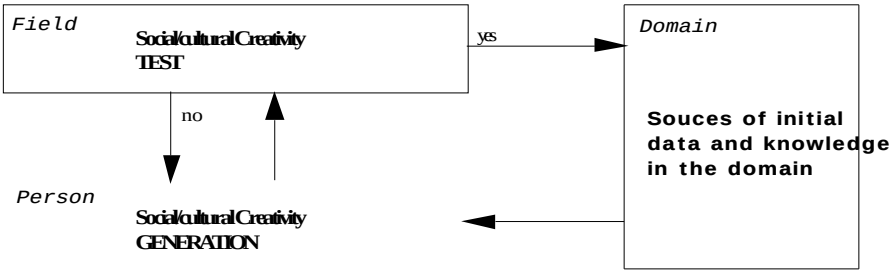

Figure 4. A model of social/cultural creativity.

Based on the preceding discussion of personal and social/cultural creativity, a better-defined framework of creativity should subsume these two levels of activities characterized by the person, the field, and the domain. Therefore, a dual generate-and-test model of creativity is diagrammed as illustrated in Figure 5.

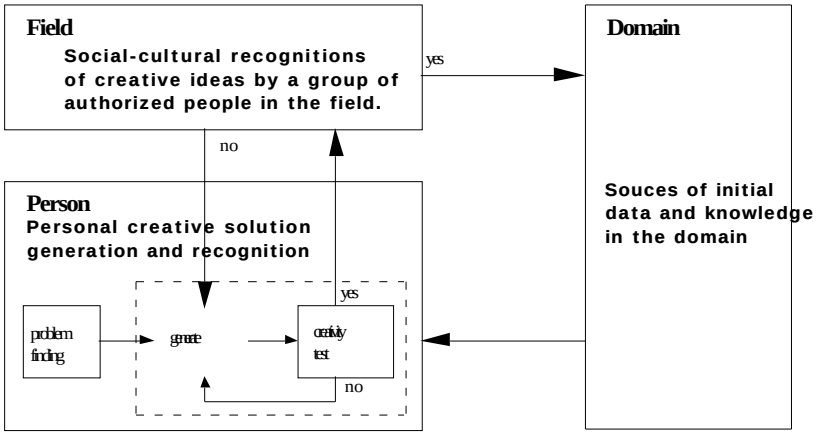

Figure 5. The framework—A dual generate-and-test model of creativity.

5. Conclusion: Implications for computer systems

Social/cultural systems are sophisticated and complex. In the search for design creativity generated by computer systems, personal creativity is a rational start; indeed, all researchers into design creativity belong at this level, including Simon (1970), Akin (1990) and Gero, Maher and Zhao (1988). As discussed previously, personal creativity can be seen as a peculiar kind of problem-solving characterized by unconventionality, originality, and persistency, as well as cognitive procedures of problem-finding, domain-specific heuristics-finding, and solution recognition. Such processes were conceptually modelled as a *creative generate-and-test* procedure in the last sections on the pursuit of creativity at the personal level.

From the implications of Simon's research, people can subjectively pursue personal creative behavior 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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