Creativity, Computation, and Interaction

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ABSTRACT
This paper takes a position on computational creativity support by focusing on two possibilities: creativity and computation, creativity and interaction. The paper starts with a definition of creativity, followed by a summary of my research in these two areas.

Author Keywords
Creativity, HCI, computation, interaction.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Creativity support can be considered in two categories: new ways of interacting with digital information that affects human perception in a way that enhances creativity, and computational paradigms that explore a search space in a way that goes beyond traditional search paradigms. The first category can be achieved with technologies such as augmented reality, tangible interfaces, immersive virtual worlds. The second category focuses more on algorithmic models that have the potential to produce creative results or to provide input to or a dialogue with the human creative process.

CREATIVITY
Taking a position on creativity, computation, and interaction is better understood if it starts with a working definition of creativity. A unified definition of creativity is difficult because of the differing expectations in different domains, and the different views on the nature of the definition as a way of recognizing creativity or as a way of being creative. The different expectations are highlighted by comparing art and science: In the art world, painting a picture or writing a poem is often considered creative, even if it is performed in an ordinary manner; in contrast, in the world of science, math, and engineering, creativity is considered to be rare and only occurs when something exceptional has been produced [13]. This may be why most definitions of creativity associate creativity with the arts, aka the creative arts. However, definitions of creativity from the fields of psychology and philosophy are more comprehensive and cover creativity in both science and art, and provide a basis for computation and creativity.

There are two major views on the nature of the definition of creativity: defining the recognition of a creative product or defining the nature of creative processes. We start with defining the recognition of creativity: creativity, whether performed by a person or computer, artist or scientist, has three characteristics: novelty, unexpectedness, and value. Novelty is usually associated with creativity and is not hard to argue as an essential characteristic of creativity. Most agree that novelty is not a sufficient condition for creativity and therefore adjectives are applied to clarify what kind of novelty is associated with creativity. Rather than characterize the kind of novelty, this definition states that there is more to creativity than novelty. Unexpectedness is an aspect of creativity that we recognize when we say that something is creative because it surprises us, or because it breaks the rules, or because it combines two or more things that usually do not go together. Value is an important characteristic of creativity. A random act or result is not sufficient for us to judge something as being creative. The creative result must somehow improve our understanding in a specific field, be valuable to the experts in the domain to which it contributes, or enhance our lives in some way. These three characteristics are necessary and sufficient characteristics of creativity. This definition is consistent with the definitions described and defended by Boden and de Bono:

- "Creativity is the ability to generate ideas or concepts that are novel, valuable, and surprising." [1]
- "At the simplest level, creative means bringing into being something, which was not there before." "The new thing must have value," and lastly, it must include the concepts of "unexpectedness and change."[1]

Definitions of creativity that focus on how creativity happens can include a very long list. Boden [1] provides three types of process, combination, exploration, and

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transformation. Here are four types of processes, including Boden's three, that are associated with creativity:

1. novel combination of familiar ideas, for example metaphor and analogy.
2. exploring parts of a conceptual space not normally considered, for example stochastic search.
3. transforming an existing conceptual space to produce a new space of possibilities, for example re-representation of a conceptual space.
4. identifying a new space of possibilities by shifting the problem space in response to searching the conceptual space of solutions, for example co-evolution of problem and solution spaces.

Defining creativity according to the kinds of processes that are likely to lead to creativity can't be complete, but it provides insight into how computation and interaction can support and augment human creativity.

CREATIVITY AND INTERACTION

Creativity and interaction is an exciting new area that provokes new ways of thinking about the purpose of human-computer interaction. The NAS report on Beyond Productivity [12] proposes that we think about how computing can enhance our experiences and to focus on the quality of the interaction rather than on the efficiency and productivity of the human while interacting with computers. While many advances have been made in developing new technologies to support creative activities, we do not have design principles for supporting creativity that are grounded in scientific studies of the use of these new technologies.

We have developed and studied the use of a tabletop system that includes augmented reality and tangible interaction [3, 4]. Our design protocol studies of architects compared design tasks performed on the tabletop with similar design tasks performed using a traditional display screen, keyboard, and mouse. The studies show that the designers exhibited more creative design behaviors using the tabletop, such as unexpected discoveries and inventing new goals, and we found a corresponding change in spatial cognition.

We have also developed and studied the use of 3D virtual world environments for collaborative design and have results that show that avatars collaborating in virtual worlds exhibit different design behaviors than the same designers collaborating while sketching on paper or a shared digital whiteboard [7]. These studies have shown that designers in an immersive environment focus more on the details of developing the design than on the higher level decisions associated with the design specifications.

CREATIVITY AND COMPUTATION

Computational models of creativity can inform our understanding of creative processes by allowing us to study these processes in an observable context. While it is difficult to observe creative processes in humans, we can follow the process when it is simulated on the computer. A framework for understanding the potential of computational processes to produce creative results is provided in [6].

Three specific approaches to computational creativity are:

1. co-evolutionary models of designing,
2. flexible indexing in case-based reasoning, and
3. curiosity-driven reinforcement learning.

These algorithms start to identify approaches to search that achieve creativity through redefining the goals of the search in response to the search experience, novel ways of combining conceptual spaces, and exploration of conceptual spaces that normally are not considered.

We have developed a co-evolutionary model of creative design, in which the problem specifications and solution space are defined as two separate populations of possibilities in a co-evolutionary algorithm [9]. The algorithm searches one space, using the latest most fit solutions from the other space as the fitness function, and in the next iteration, the algorithm repeats but searches the other space. The result of this process is the ability to change the problem definition in response to the search for solutions, as well as to search for solutions in response to the current problem definition.

We have developed a case-based reasoning approach to creative design, in which a flexible indexing approach to searching for relevant cases assumes an iterative process [5]. The initial problem definition is a starting point for searching case memory, but the human designer changes the index in response to what is found, allowing the search process to focus on the most interesting or relevant cases rather than the closest match.

We have developed a curiosity driven learning approach to creativity, in which a computational model of curiosity based on novelty and interest provides the reward function for a reinforcement learning algorithm. This approach allows search to be guided by novelty rather than by a specific goal. We demonstrated this approach to learning in a proactive information display panel [10], in nonplayer characters in a game world [11], and in the design of places in virtual worlds that are curious about the humans inhabiting them [12].

QUESTIONS RELEVANT TO COMPUTATIONAL CREATIVITY

1. How does our knowledge of the characteristics of creativity and creative processes inform the design of new interaction technologies that support creativity?
2. What are the characteristics of algorithms that enhance or support human creativity through interaction?
3. How do algorithms that are inspired by human creativity influence the development of computational support for creativity?
4. Should the design principles for HCI when efficiency and productivity are important be

different from HCI that enhances creativity?

AUTHOR INFORMATION

I joined NSF in 2006 as a Program Director with the purpose of starting a funding emphasis on creativity and computing. This has lead to a funding program called CreativeIT. This program was developed after running a workshop at NSF with members of the research community and NSF Program Directors. This program has funded approximately 55 research proposals and 10 workshops.

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