

GUEST EDITORIAL

Creativity: Simulation, stimulation, and studies

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Creativity is traditionally a topic of philosophical and scientific study considering the scenarios and human characteristics that enable creativity. More recently there has been an increased interest in studying the properties of computational systems that exhibit computational creative behavior and the creator's cognitive processes when computers enhance human creativity. Developments in computer science and information technology are enhancing and augmenting the capability of human creative thinking and problem solving through access to larger information resources, multimodal interaction, and algorithms that facilitate the generation of creative ideas and products, exhibiting characteristics of novelty, value, and unexpectedness among others. We are still in the early stages of studying computational creativity where we are exploring our understanding of human creativity at the same time as exploring how computing simulates or stimulates human creative thinking.

When studying creativity, we can analyze how creativity occurs focusing on the *processes* that produce creative artifacts, and we can analyze what makes an act creative focusing on how we *evaluate* an artifact to determine if it is creative. Research on creativity can focus on human creativity through psychology studies, computational creativity through philosophical and artificial intelligence studies, and human–computer creativity through human–computer interaction studies. The psychological study of human creativity tends to focus on the characteristics of creative people and the environment or situations in which creativity is facilitated. In cognitive studies, the research methods are frequently based on protocol analyses and experimental settings in order to provide systematic ways of studying thought processes of a person when he/she is exhibiting characteristics of creativity. The study of computational creativity, although inspired by concepts of human creativity, is often expressed in the formal language of search spaces and algorithms.

The studies in this Special Issue focus on creativity in designers from the fields of architecture, engineering, and computer science. Whatever the field, there is a constant challenge to introduce creative ideas and go beyond existing or expected

solutions. In pursuing creativity there is a need to generate ideas or solutions that can be recognized, can satisfy requirements and constraints relevant to the field, and can be novel and surprising, as well as exhibit other characteristics associated with creativity. The articles in this Special Issue provide an overview of the current methods that are used to study creativity, with the most prominent method being protocol analysis. All of the articles focus on studies of human creativity, and most focus on how to stimulate creativity by showing images, providing rule-based knowledge, or considering the level of abstraction of the problem description. There is a trend in the results presented in the articles in this issue that computing has a significant role to play in stimulating creativity by providing additional information to the designer while he/she is designing. Each paper explores a different assumption about what that additional information should be and how that information impacts the design process.

The Special Issue has two types of articles: studies and stimulation. The first two articles report on studies of creativity: the first article provides an overview of the study of creativity, and the second article describes a study of engineering design creativity with respect to specific formal models of engineering design. The remaining four articles report on different approaches to stimulating creativity and their effect on designers. These articles provide the foundational research for developing computational systems that stimulate and/or simulate creativity.

The first article by Puccio, Cabra, Fox, and Cahen, “Creativity on Demand: Historical Approaches and Future Trends,” is an invited article that presents an historical perspective of psychology studies and creative thinking in humans. The article documents the recent increasing interest in creativity by researchers and businesses. The two interests come together as businesses realize the importance of creativity in maintaining a competitive edge and want to stimulate creativity in their employees. The article highlights creativity methods, such as lateral thinking and synectics, that have evolved over the years and speculates on how technology “may serve to shape the deliberate application of creativity.”

In Srinivasan and Chakrabarti's article, “Investigating Novelty–Outcome Relationship in Engineering Design,” they perform a protocol analysis of eight design sessions and find a

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positive correlation between the number of ideas produced during the engineering design process and the novelty of the design concepts. Their article provides a review of different approaches to measuring novelty in creative design and provides the authors' approach for measuring the novelty of a design using constructs from the function–behavior–structure model and their own design model. Their measurement of novelty is based on similarity at different levels of abstraction of the design space.

Christensen's article "Images of Users and Products Shown During Design Processes Increase Users' Willingness to Use the Design Outcome" reports on a study of the usefulness of displaying images of end users and products during the design process. His premise is that creative designs are expected to be novel, and we need to better understand how we can improve the usefulness of creative designs. He provides a review of analogical reasoning from the perspective of what information is more easily transferred. He reports on a study on the effect of showing images to a designer concerning how end users may use their product as well as showing images of potential analogies. His results show that including images of end users during the design process improves the usefulness of the creative designs that are generated.

Jin and Benami's article "Creative Patterns and Stimulation in Conceptual Design" describes a protocol study of designers in the mechanical engineering domain and shows that more ideas are generated when the designer is given stimulation as forms and behaviors that may be relevant to the given design task. They find that stimulation as function and knowledge is not as effective, and may lead to fixation. Their article provides a review of creative cognition and its relevance to literature in engineering design. The design processes being encouraged by stimulation are based on analogical reasoning processes.

Al-Sayed, Dalton, and Hölscher's article "Discursive Design Thinking: The Role of Explicit Knowledge in Creative Architectural Design" reports on a protocol study of architectural designers to explore the effect of making spatial knowledge explicit on the design process and product. Their results show that explicit knowledge as rules improves the design process and the design product. Their premise is that architectural design is a creative process and that stimulation that improves this process provides insight into how we can better support creative design. Their article provides a significant review of the use of linkography as a method for tracking the content in a design protocol.

Zahner, Nickerson, Tversky, Corter, and Ma's article "A Fix for Fixation? Rerepresenting and Abstracting as Creative Processes in the Design of Information Systems" contains a study of information systems designers in which abstract and concrete problem descriptions were given and the designers were asked to generate solutions. The study shows that the variety of solutions is positively correlated with more abstract descriptions and that abstraction and rerepresentation are successful approaches to increasing the originality of the solutions generated. However, originality of solutions is not positively correlated with correctness, and the authors propose that abstraction and rerepresentation aids may be useful during divergent thinking but not during convergent thinking.

Specific contributions made by the articles in this Special Issue have some common themes:

- The role of *analogy* in creativity is critically reviewed and further studied in Jin and Benami, Christensen, and Zahner et al.
- Increasing our understanding of the correlation between the *variety of ideas* generated and the originality of the ideas is a focus in Srinivasan and Chakrabarti, Jin and Benami, and Zahner et al.
- Studying and measuring *novelty and originality* in creativity is focused on in Srinivasan and Chakrabarti, Jin and Benami, and Zahner et al.
- The use of *protocol analysis* in studying design cognition is reviewed and applied in Srinivasan and Chakrabarti, Jin and Benami, and Al-Sayed et al., with a significant focus on linkography in Al-Sayed et al.

In summary, this Special Issue provides a rich resource for researchers that are studying creativity and the role that computational systems can play in stimulating human creativity. The research reported on novelty, idea generation, and the role of formal models and knowledge in creativity provide the basis for further research on simulating creativity in computational systems.

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Nathalie Bonnardel has been a Professor of cognitive psychology and ergonomics at the University of Provence, Aix-Marseille I, France, since 2006 and a member of the University Institute of France (I.U.F.). She received a PhD in 1992 after a research internship at the National Institute of Research in Computer Science and Automatics (INRIA). From 1992 to 1994 she was a Research Associate at the University of Colorado at Boulder. From 1994 to 2006 she was an Assistant Professor and Associate Professor at the University of Provence, where she received an HDR (habilitation) in 2004. Dr. Bonnardel is Director of the Department of Cognitive and Experimental Psychology and Director of the Master's degree program in

Ergonomics: Human Factors and Engineering of Information Systems. Nathalie is also in charge of the research team on Design, Written Production, and Multimedia Systems in the Research Center in Psychology of Cognition, Language and Emotion (PsyCLE). Her research explores designers' cognitive processes, such as analogy making and evaluation processes, and contributes to the development of computational systems adapted to the designers' level of expertise.

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