Preface: Advances in Computational Creativity Technology

Computational creativity is the art, science, philosophy, and engineering of building computational systems that demonstrate behaviors that would be deemed creative by unbiased human observers. There has been much recent progress in this field of research, including formalizing what it means for software to be creative and developments in many exciting and valuable applications of creative software in the sciences, the arts, cooking, literature, fashion, product design, and elsewhere.

This special issue of the *IBM Journal of Research and Development* explores both theoretical contributions to computational creativity research and groundbreaking computational creativity systems in a variety of domains. While creativity, such as intelligence, is difficult to define, the theoretical papers in this issue explore how to evaluate creativity and the theoretical limits of creativity. The computational creativity systems described in the papers provide a cross-section of the types of applications that are emerging from the research community. They provide both creative designs and powerful tools to assist human designers in their creative tasks. The applications range from designs meant to appeal to human senses such as color choice, visual composition, and recipe generation to more cognitive tasks such as software composition, tagline generation, and narrative generation.

The first three papers in this issue consider computational creativity from a theoretical perspective. The first paper, by Wiltgen and Goel, examines perhaps the most central, but less studied, of the problems in computational creativity: evaluating a design for creativity. Focusing on the early stage of conceptual design, the authors propose an evaluation methodology based on a computational theory of analogical comparison. They illustrate the theory in the context of biologically inspired design and formulate an artificial intelligence agent, Design Evaluation through Simulation and Comparison (DESC), to perform the evaluation.

The second paper, by Varshney, uses information theory to study mathematical limits of creativity. Focusing on combinatorial creation, the author decomposes the evaluation of an artifact along the dimensions of novelty and quality and provides abstractions of both. The fundamental tradeoff between the two is precisely studied, and it is shown that creativity becomes more difficult as a field matures.

Whereas the first two papers consider evaluation of creativity through analogy and through the two dimensions of novelty and quality, the third paper, by Agrawal et al., examines evaluation of creativity along seven different dimensions: novelty, value, surprise, influence, coherence, correctness, and comprehensibility. The authors then discuss the relative importance of each of the dimensions in different application domains.

The paper by Khabiri et al. is the first in this issue to describe a computational creativity system. The authors explore color palette design for artifacts intended to convey a message and fit with the character of a brand and product category. The paper describes a range of applications from product package design, to movie poster design, and even a cognitive dress design. The paper shows how any palette design needs to consider multiple quality assessment criteria from aesthetics to message, in addition to novelty when evaluating which designs to recommend.

Karimi et al. describe a second computational creativity system in their paper, exploring co-creation based on the visual similarity of sketches representing different concepts to spur ideation. For example, the sketch of a traditional alarm clock with an analog face and bells on each side is visually similar to the sketch of a bear face and could suggest combining the concepts to create a bear-faced alarm clock. The system accounts for the fact that a single concept may have multiple visual representations. In the case of an alarm clock, we could have either an analog-face clock or a digital-face clock. By chaining together sketches that are related by concept similarity and visual similarity, the system could start with a sketch of a digital alarm clock, link it to an analog clock then a bear face, and suggest a sketch that combined a bear face with a digital clock. The approach illustrates how using a data-driven approach and switching between representations, sketches and concepts in this case, can enable ideation.

In the sixth paper in this issue, Ray et al. study the problem of creative tagline generation for product advertisement. Their proposed framework includes a knowledge graph (manually created for the fashion domain), a CopyLSTM (the modified LSTM) network that understands key:value pairs while generating taglines, a neural paraphrase model to generate a variety of paraphrases to the taglines, and a natural language generator for generating style tips to help user interact with the framework.

In the seventh paper on Chef Watson, Varshney et al. describe a system for creating innovative recipes and menus. Chef Watson analyzes large collections of data, recipes, chemical breakdowns, and olfactory pleasantness to create an appropriate knowledge base and combines the knowledge base with results from psychological models of human perception of flavor and olfactory pleasantness. Chef Watson first identifies a set of ingredients that are predicted to taste and smell good but are unique and fit with the desired cuisine and dish type. Thereafter, the system generates a plan or set of instructions for turning the ingredients into the desired dish, taking into account the subtleties of human language when generating the recipe. The system also suggests menus, consisting of a set of

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dishes where the individual ingredients are related in terms of themes found in the source recipes. Compared to the other systems described in this issue, Chef Watson produces the most complete designs and has been most widely deployed and evaluated.

The eighth paper of this issue, by Gervás et al., addresses one of the fundamental creative tasks for humans, i.e., storytelling narratives. The authors propose a computational model for storytelling by looking at the problem from five perspectives: the narrative structure, the evolution of a given world, the evolution of characters, communicating a given state or the changes of the world, and the suspense induced on the reader. To integrate them together, the authors further explain a theoretical model and a technological framework.

While the previous few papers discuss specific computational creative solutions, the ninth paper, by Martins et al., investigates the software infrastructures that support exploration of computational creativity. The authors propose DivagoFlow, a workflow infrastructure that helps implement a concept generator based on the conceptual blending framework. A few use cases based on DivagoFlow are also discussed.

The range of human creative endeavors is vast. To do almost any task well and advance the state of the art requires some level of creativity to deal with resource limitations and an ever-changing environment, including technological advances. We hope you enjoy the articles in this issue that explore both the theoretical basis for computational creativity and how computational creativity systems can assist people in their creative endeavors.

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