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**Guest Editorial**

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# Design creativity

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Engineering design relies on creative thought to produce new and exciting products, systems, and services. The study of creativity provides many opportunities for interdisciplinary research between engineering, cognitive science, and computer science. This special issue aims to capture a snapshot of some of the best work at this intersection of areas. The scope of this special issue was broadened in relation to the traditional AIEDAM scope to include papers that explicitly discuss creative thinking, types of reasoning, and explicit use of knowledge; such topics often influence the foundation of creative AI design systems. Papers were reviewed by experts in the fields of engineering design creativity, with at least three reviewers per paper.

Papers were solicited in two main areas: foundational theory, such as understanding how, why, and what makes designs or designers creative, so as to provide useful performance bounds on computational creativity; and empirical outcomes, such as creative results, processes, or systems. The special issue has distinct themes that emerged naturally among the collection of papers.

Within the foundational theory area, there is a strong focus on measuring creativity and design outcomes, with three of the seven papers (Kwon and Kudrowitz, 2018; Sääksjärvi and Gonçalves, 2018; and Ranjan *et al.*, 2018). The measurement of creativity is an important part of design research, particularly when considering the intersection with artificial intelligence. As we strive for larger, more realistic data sets and more rigorous methods for formalizing design science, we may turn to AI to help process qualitative data more efficiently and objectively. These human subject-based studies will be the basis for the potential development of future automation in these areas.

It is important to recognize, separate from any future automation, that the measurement of creativity and design outcomes is intrinsic to the validation of the computational design support systems, such as those described next in the empirical outcomes area. One additional paper within the foundational theory area is that of Studer *et al.* (2018), focusing on studying designer behavior in exploring problems during design, tying neatly into the empirical outcomes of supporting design space exploration with computational tools.

Within the empirical outcomes, three papers (Siddharth and Chakrabarti, 2018; Luo *et al.*, 2018; Han *et al.*, 2018) share a common goal of support using design-by-analogy with data-mining techniques, each addressing the problem in unique ways with case study validations of their systems.

## Foundational theory

Sääksjärvi and Gonçalves study existing definitions of how past literature measures creativity, and propose the addition of "meaning" as one aspect not well covered by existing metrics. They conduct a series of studies in which design engineering students generate ideas and then have design students and independent raters label those ideas using a variety of text identifiers. They use Factor Analysis to identify meaning-related tags as accounting for significant variances in idea ratings, even after accounting for other common factors like novelty and usefulness.

Kwon and Kudrowitz address the fundamental question of whether audiences can disentangle their assessments of idea quality from how an idea is presented. They find a positive correlation between both idea and presentation quality – that is, ideas that were presented better generally also were rated as being higher quality, even when judges were asked to purposefully disregard differences in presentation quality.

Ranjan *et al.* develop a creativity assessment method that incorporates novelty and requirement satisfaction as measures of creativity, intended for use across any of the stages of the design process. They apply their creativity assessment method in a case study to illustrate how it can be used in practice.

Studer *et al.* present a qualitative analysis aimed at characterizing how designers explore and change problems during designing. They identify 31 patterns of problem exploration, based on a database of 252 collected design problems. They conjecture that the patterns are generalized strategies that can guide designers, and that they may also be useful for computational tools that support designers as they explore design problems.

## Empirical outcomes

Siddharth and Chakrabarti report on experiments with a web-based tool that supports engineering design-by-analogy using a rich, searchable, multi-modal knowledge base of biological systems. They measure both novelty and requirement-satisfaction to indicate the creativity of the resulting design solutions that were generated by designers using (a) a conventional text-with-image representation and (b) their knowledge base.

Luo *et al.* propose a visual ideation aid – the Technology Space Map – that uses text similarity between patents and network visualization to provide a high-level overview of different technology spaces (via their patent clusters) wherein designers can drill down to specific patents for stimuli if needed. They demonstrate the effectiveness of the tool on multiple rapid ideation tasks, including rolling robots and new venture identification.

Han *et al.* combine design-by-analogy with ontological frameworks to support creative conceptual design with a computational tool, called "the Retriever". An initial case study has indicated that the tool can increase fluency and flexibility, usefulness, and originality in ideation.

This collection of papers captures some of the current work in design creativity as it influences the fields of artificial intelligence for engineering design, analysis and manufacturing, spanning important cognitive work that forms the basis and inspiration for intelligent systems, to critical computational support to help designers achieve their most innovative outcomes.

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