Journal of Mechanical Design

Editorial

A journal like JMD is the product of an extensive collaboration of many individuals: authors, editors, editorial staff, and production staff. As technical editor, an important role for me is to make sure the journal expresses the scholarly interests and intellectual desires of our community, and help to plan its future directions. I have been using the editorial "podium" to communicate my thoughts and incite some dialogs. In the same spirit, I have started to invite members of our community to do the same using this editorial page. I am pleased to introduce this first guest editorial below provided by Jonathan Cagan of Carnegie Mellon University, with my thanks to him for responding positively to my request.

Panos Y. Papalambros

Cognitive-Based Engineering Design: An Emerging Direction of Engineering Research

Over the past few decades, a formality to the synthesis process has begun to emerge, and with it a rich and diverse community of researchers and practitioners. To further study and advance the engineering synthesis process means several aspects of the process, often thought of as the domain of other disciplines, must be embraced by the engineering research community. One particular area that is ripe to significantly advance our understanding of design is the cognitive mechanisms that people use to create something new. That engineers can use physics to their advantage continues to be fundamental to engineering, but how they think to manipulate physics is equally fundamental. However, engineering researchers have only recently begun to embrace the cognitive and social sciences as a means to advance the engineering process. This is one of the most fruitful avenues to advance the state of design theory and practice.

Several areas of cognition are particularly relevant to engineering design:

- Fixation: what causes people to become stuck in problem solving and how to overcome it;
- Representation: how mental representations aid in problem solving and how they (dynamically) change to improve outcome or overcome fixation;
- Analogy: how concrete and abstract analogies stimulate relevant solutions, and how the analogical process itself stimulates the creative process;
- Group Cognition: how the cognitive processes of individuals combine and collaborate for a group level representation and performance, and the advantages and disadvantages of group interaction;
- Computational Studies: how models of cognition can be emulated on the computer, how those models can improve design tool performance, and whether exploration of those models can give insight into cognitive mechanisms of innovation;
- Expertise: how richer representations and knowledge can accelerate design performance.

Cognitive scientists use rigorous methods to uncover mechanisms in our brain. They seek to identify, isolate, and understand the ways people think about problems and their solutions. Cognitive scientists seek to understand what mechanisms are appropriate, what are their bounds, and when they are optimal. In many ways, their process of inquiry is much like that of an engineer seeking to understand a new phenomenon and its context of use.

A cognitive experiment is designed to isolate and explore a single attribute, several noncompounded attributes, or few compounded attributes. The more compounded attributes tested, the larger the subject pool needs to be. A pilot experiment is run to demonstrate the effectiveness of the experiment. The cognitive scientist seeks statistically valid conclusions, requiring large numbers of data, and, accordingly, at times large numbers of subjects. Often, phenomena found in a given experiment must be shown to be generalizable through multiple experiments. The statistical rigor of the cognitive study is alone a model for design research, and verifies the accuracy of the findings. However, there are other attributes within the cognitive scientists' expertise in experimental design and in the isolation of characteristics of the human mind that benefit engineering design research.

As an engineer, I find collaborative projects with cognitive scientists not only intellectually rewarding but critical to the success of my research in this area. Unless we are trained in the science of cognition, it is difficult to understand the best methods to apply and the rich literature of cognitive knowledge from which to learn and build. There are several researchers in engineering and psychology now active in cognitive-based engineering design research. In my collaborations with cognitive scientists, we have targeted specific cognitive phenomena, contributing to the cognitive literature, with a hypothesis of how those same phenomena apply in engineering design. We have taken those phenomena and then designed engineering synthesis studies to verify our hypotheses of domain transfer. Through this process, we can verify design process rules of thumb and develop new understandings of the design process. We have also more informally used cognitive insights to develop generative design algorithms. In our work, we have built on the cognitive literature that, at times, goes back over 80 years. I have found these collaborations fruitful, stimulating, and motivating. Cognitive scientists equally benefit from collaboration with engineers. They gain access to real problems, actual and sophisticated models of physical systems, engineering research tools, connection of their ideas to the engineering domain, and access to a population of domain subjects.

JMD is the only ASME journal devoted to design, the synthesis process, but still primarily focusing on design analysis. We have the opportunity for JMD to become a forum for cognitive-based engineering design research. Cognitive science is a groundbreaking direction for design theory, methods, and practice. The mechanical engineering design community can be a leader by developing and supporting this critical and rewarding area of engineering research.

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