

Guest Editorial

User Needs and Preferences in Engineering Design

Addressing user needs and preferences is critically important in developing innovative and successful engineered products and systems. The task is inherently challenging due to the heterogeneity of user needs and the difficulty of modeling human behavior and preferences. In addition, it remains a challenge to integrate user preferences with technical and economic requirements during the engineering design process. The past decade has seen a significant growth in user-focused design research that introduces principles from different domains, such as market research, economics, cognitive science, and social science. However, there is still a lack of integration of these methods, either qualitative or quantitative, for directly supporting engineering design decisions. It is therefore imperative to develop interdisciplinary design approaches to address “interface” issues among different domains and engineering design, considering market demand, usage context, social behavior, environmental impact assessments, and other factors.

With this in mind, we organized this Special Issue to gather state-of-the-art research in user needs and preferences, with the goal of identifying new research frontiers in this area. Over ninety technical papers were submitted for review to the Special Issue. All papers were subjected to a rigorous peer-review process with quality standards set by ASME. While the three of us served as associate editors for most of these manuscripts, we would like to thank *Journal of Mechanical Design* associate editor Dr. Christopher Mattson for his assistance coordinating the reviews of some of the papers. We are also very grateful to all reviewers who helped review these papers.

This Special Issue collects fourteen papers including one technical brief. These papers are organized into four groups based on common themes: (1) User needs and preferences elicitation, (2) Incorporating user needs into engineering design, (3) Choice-based preference modeling and design, and (4) Modeling user behaviors and activities adapted to use contexts. The following summaries provide brief snapshots of these papers and the relationships between them.

User needs and preference elicitation. Elicitation of user needs and preferences is ultimately important for directing product design activities and decisions. While understanding user needs is focused on identifying desired features and functionalities of a product, elicitation of user preferences emphasizes understanding how users consider multiple product attributes simultaneously. This Special Issue features three papers that focus on emerging techniques for user needs and preference elicitation. *Zhou and Jiao* present a methodology for eliciting latent customer needs via use case analogical reasoning from sentiment analysis of online product reviews. Data mining and artificial intelligence techniques, such as fuzzy support vector machines, text mining, and case-based reasoning, are used to build sentiment prediction models and extract critical product attributes as a part of the proposed methodology. A case study of the Kindle Fire

HD 7 inch tablet is used to illustrate the potential and feasibility of the proposed method. Motivated by capturing heterogeneous user needs, *Tuarob* and *Tucker* present a set of mathematical models that mine social media networks for lead users and their preferences for specific products. The authors collect approximately 2.1 billion social media messages in the United States during a period of 31 months in order to determine whether lead user preferences are discoverable and relevant to next generation cell phone designs. In the last paper of this group, *Schaffhausen* and *Kowalewski* focus on methods for increasing user-generated needs. They present three studies that evaluate three specific types of stimuli, including prompts (a type of thought exercise), shared needs, and shared context images to help users describe higher quantities of needs. The results of their studies indicate that specific stimulus types can significantly impact the quantity of needs collected, and the incentive structure appears to influence user behavior. Products studied cover general household areas including cooking, cleaning, and trip planning.

Incorporating user needs into engineering design. While the previous group of papers focuses on capturing user needs, this group of papers focuses on better integration of user needs into the engineering design process. *Rasoulifar*, *Prudhomme*, and *Eckert* focus on mediation layers between consumers and design teams and the potential loss of focus on consumer needs and preferences across those layers. They carry out a series of interviews to understand how communication between product designers (who focus on the overall look and feel of the product) and engineering designers (who focus on technical performance and fabrication) can be improved to make sure that consumer needs and preferences are embodied in the final product. They conclude that there is a need for a formal tool to communicate aspects of consumer preference, such as branding and Kansei concepts, that are often communicated among designers in very informal ways. *Fuge* and *Agogino* apply pattern analysis to a repository of design case studies to discover the types of methods that designers most frequently use to identify user needs and preferences for developing world applications. They base their analysis on HCD Connect, an online toolkit developed by the global design firm IDEO. Their findings indicate that certain types of design tools and methods complement one another frequently in case studies and that for developing world applications, in particular, professional designers tend to focus heavily on methods that facilitate understanding the needs and preferences of the targeted developing community. In another article focused on developing world applications, *Judge*, *Holttä-Otto*, and *Winter* demonstrate how developing country users can serve as lead users for customers in developed markets. Because developing world users often demand high-performance, low-cost solutions, those products can serve as a suitable platform for users in developed markets who often seek similar characteristics. The authors leverage the Leveraged Freedom Chair (LFC) as a basic platform for developing a low-cost, off-road wheelchair for developed markets using a process called reverse innovation. *Mohedas*, *Daly*, and *Sienko* investigate how novice designers define product requirements in the early stages of design and correlate the quality and validity of those requirements to specific types of information gathering behavior. Specifically, they find that novice designers who utilize multiple information sources generate requirements that are better tailored to the design context. Once user needs are identified, the next step is to generate concepts to address those needs. *Haggman, et al.* compare the use of foam prototyping, CAD modeling, and sketching as alternative techniques for generating ideas

and investigate their impact on user perceptions of the resulting designs. The results suggest that prototypes are generated more quickly than CAD models or sketches and that resulting designs are perceived as more novel and user-friendly.

Choice-based preference modeling and design. Customer choice modeling is gaining increasing attention in engineering design because it bridges the gap between modeling user preferences and predicting market demand as a function of product design attributes and target market descriptions. However, the use of a choice modeling approach is challenged by the formation of appropriate choice sets. *Du* and *MacDonald* extend the cancellation-and-focus (C&F) model, developed by psychologists to study decision-making, to investigate how consumers make choices under the influence of either visual or text-based representations of product features. The implications are explored using a survey instrument and eye-tracking technology. To overcome the challenge of missing choice set information, *Wang* and *Chen* propose a data-driven network analysis approach to predict individual choice sets in customer choice modeling. Their approach takes into account product associations and customer heterogeneity and applies data analytics to mine existing customer choice set data for predicting choice sets in a new choice modeling scenario. The approach is demonstrated for vehicle choice. The last paper in this group from *Long* and *Morrow* explores the importance of capturing consideration rules for optimal designers. Using simulated data, their research supports the claim that designers should carefully identify consideration behaviors before optimizing product portfolios and that modeling heterogeneity in non-compensatory screening is more valuable than heterogeneity in compensatory trade-offs.

Modeling user behaviors and activities adapted to use contexts. Expressing needs and preferences *in advance* for a product or service is sometimes challenging, especially when those needs and preferences are strongly linked to the context in which the product or service is consumed. Ultimately, designers may need to model and simulate user behaviors and activities linked to that product or service in specific contexts. The three papers in this group address the challenge of modeling user behaviors and activities. In the first paper (a technical brief), *Zaraket*, *Yannou*, *Leroy*, *Minel* and *Chapotot* propose an activity-based model for forecasting energy and water consumption of households for residential building design. A user-centered statistically-derived approach correlates occupants' profiles (socio-economic and demographic) on the one hand, to quantities of domestic activities and appliance ownership and energy and water footprints on the other hand. This model results in more accurate energy and water consumption forecasts. In the second paper, *Cor* and *Zwolinski* study the influence of low-complexity products like coffee makers on users' environmental behavior. In turn, the product – in this case, a coffee maker – may be designed to trigger different sustainable behavior strategies for delivering the expected service, i.e. a satisfactory cup of coffee. In the last paper, *Bekhradi*, *Yannou*, *Zimmer*, *Farel* and *Chandra* study disparate literature on elderly falls to build a space of usage scenarios or segments. They present a simulator that evaluates the usefulness of potential design solutions based on their coverage of a tessellation of usage segments. The potential of poorly-covered usage segments is assessed for providing insights during the early stages of innovation. In general, modeling user behavior, user activities, and usage contexts allows designers to go beyond the expression

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of a priori needs and preferences and build a better understanding of how, when, and where products are actually used and by whom.

The papers in this special issue range from qualitative methods for better understanding and capturing user needs and quantitative methods for modeling consumer choice. They consider user needs and preferences from perspectives as varied as modeling customer choice at the point of purchase to using latent needs from developing country users as the platform for high-performance, low-cost products for developed markets. Future research may not only build on the concepts embodied here but also branch into new and exciting research opportunities in crowdsourcing, social computing, web-based user analysis, human-centered design, network analysis, data mining, and many other fields. It is our hope that this Special Issue will stimulate further research and discussion on this topic, thus helping the community make new, rigorous advances in capturing user needs and preferences in engineering design.

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