EDITOR'S COMMENTS

Diversity of Design Science Research

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Design in the sciences of the artificial is concerned with what *might* be, with "changing existing situations into preferred ones" (Simon 1996, p. 130). As a multifaceted concept, design has been studied by IS scholars as an object, process, and capability. As a multidisciplinary concept, it has received significant attention across various traditions of research in the IS community. As a multilevel concept, it has been examined to uncover interdependencies across levels of analysis. As a concept that can redefine human experiences, it has led to the development of problem solving and innovation practices that embody design thinking (Buchanan 2015).

We have seen significant discussion in the IS literature about the design science paradigm, which is concerned with developing and evaluating new and innovative IT artifacts to solve problems and through the process contribute to knowledge (Hevner et al. 2004). The discussion has been wide-ranging and has encompassed the distinctive characteristics of design science research, the knowledge contributions of design science research, and how design science research can be conducted and presented effectively and evaluated appropriately (e.g., Gregor and Hevner 2013; March and Storey 2008; Peffers et al. 2007; Sein et al. 2011).

A look at papers published in *MIS Quarterly* and other major IS journals reveals important commonalities in the practice of design science research but also reveals important differences. There are observable genres of design science, which differ with respect to the problems that are addressed, the types of artifacts that are designed and evaluated, the search processes that are used to create and refine the IT artifacts to solve problems, and the types of knowledge contributions that are made. For example, consider the types of problems that are addressed and the artifacts that are developed across a few genres: the *computational genre* is concerned with solving business and societal problems by developing computational models and algorithms, the *optimization genre* is concerned with solving operational and decisional problems by developing optimization and related models and heuristics, the *representation genre* is concerned with representing complex phenomena by developing methods and grammars, and the *IS economics genre* is concerned with solving problems related to economic activities and systems by designing mechanisms for the conduct of activities and economic exchange. Clearly these genres are neither exhaustive nor are they mutually exclusive, but they illustrate the diversity of design science work in the IS community.

This editorial presents a diversity of perspectives related to design and design science research. I invited a few scholars who have been actively engaged in research related to a certain perspective of design or a certain genre of design science to comment on key premises and quests, types of scholarly contributions, exemplar articles, misunderstandings among authors and reviewers, and exciting avenues for future research related to the genre or perspective. I conclude with some observations on the diversity of design science research and commonalities and differences across genres.

Design Thinking for IS Research: By Youngjin Yoo

The design thinking perspective: Design thinking is a set of broad approaches to organizational problem solving and innovation that are based on the tradition of human-centered design practices. It emphasizes an iterative, visual, and multidisciplinary design process using contextual observation, scenario building, and rapid prototyping, among other tools, to problem solving and innovation that rapidly moves from gaining deep and holistic insights on users, problems, and situations, to idea generation and testing, then implementation. It focuses on "wicked problems" in organizations (Buchanan 1992). A recent issue of *Harvard Business Review* declares design thinking's "coming of age" (Kolko 2015). Once used primarily for product design by design consulting agencies like IDEO, design thinking is now routinely used as a tool for innovation (Gruber et al. 2015). Consumer technology companies like Apple and Samsung, as well as hospitality industry players like Marriott and AirBnB, have decisively embraced design thinking to create superior user experiences. Even traditionally conservative healthcare providers like Kaiser Permanente and Mayo Clinic have established a separate unit dedicated for patient experience, using design thinking as their primary tool for innovation. Samsung has over 1600 designers not only covering traditional product and communication design, but also user experience (UX) designers, anthropologists, and engineers (Yoo and Kim 2015).

Historical emphasis on design in the IS discipline: While design thinking is a relatively recent term, some of the key principles that underpin design thinking are not and many of them are deeply connected to IS research tradition. Early scholars in our field advocated that IS scholars should focus on wicked problems (Mason and Mitroff 1973). The importance of the user's participation in systems design has been a significant theme that runs through the history of the discipline (Boland 1978). The idea of participatory design, started in the Scandinavian IS tradition, has had a major impact on the way large systems are designed in practice (Bjerknes et al. 1987). The use of iterative design and rapid prototyping are recognized as important elements of the agile method that has emerged as an important topic among IS scholars (Ågerfalk et al. 2009). The importance of understanding the social context of use has been a major theme in the qualitative IS research tradition (Checkland 1981). As ubiquitous and mobile technology became important elements of enterprise systems, scholars emphasized physical and temporal contexts as important elements of systems design (Yoo 2010). After all, design is one of the core threads that connects different strands of intellectual foundations of the IS field (March and Storey 2008).

While both IS research and design thinking practice share many underlying principles, there are two aspects of design thinking that are particularly important to underscore for IS research concerned with design including those in the tradition of design science research. First, design thinking is considered to be "an art of creative inquiry" (Buchanan 2015, p. 15) in "an artificial world, a world of artifacts" (Dahlbom 2002, p. 9). Unlike the science of nature, Simon argues that scientific endeavors in an artificial world should be concerned "not with the necessary but with the contingent—not how things are but how they might be—in short, with design" (Simon 1996, p. xii). Such emphasis on the creative inquiry of man-made artificial worlds makes design thinking inherently indeterminate, contested, and radically future-oriented.

Second, the primary concern of design thinking is human experience (Gruber et al. 2015). In design thinking practice, artifacts are understood as means to induce *desirable*, *feasible*, and *viable* human experiences. To the contrary, most IS research centers around IT artifacts and their design, use, and consequences. In design thinking, what is being designed is the experience itself that comes from the use of IT artifacts, whereas in IS research, the goal is to design better artifacts and the purpose of inquiry into user experience is to design a better system. The evaluation criteria in IS design research is based on novelty and utility of IT artifacts and the effectiveness and efficiency in the performance of the given task by the artifacts (March and Storey 2008).

Recognizing the importance of creating desirable user experience, leading software vendors like SAP and IBM have wholeheartedly embraced design thinking in their software development process (see https://designthinkingwithsap.com and http://www.ibm.com/design/thinking/). Such a recognition is not merely a change in their design tools, but represents a deeper and fundamental cultural change (Buchanan 2015).

Some opportunities for IS research: IS scholars can deepen our understanding on the linkage between digital artifacts and human experiences by explicitly embracing design thinking practices in their research. Such a vision has appeared from time to time in our field. For example, Dahlbom (2002) argues that the IS discipline should be "archeology of the future" (p. 33). Just as traditional archeologists reconstruct an ancient culture in terms of few technical artifacts left behind, he argues, IS scholarship based on design thinking should describe some possible future cultures that could be built on the type of IT artifacts we are building. Similarly, Yoo (2010) calls for "experiential computing" where everyday human experience is inseparably integrated with digital artifacts. As our contemporary artificial world is increasingly being digitalized, a large portion of our lived experiences are computed. Our choice of food, friends, news, music, and movies are shaped by ranking algorithms. Our sensory experiences are increasingly digitally mediated. The sociality in the social media space is computed (Kallinikos and Tempini 2014). IS scholars can build a strong program of research to build and validate a new breed of theories and practices of design thinking that focus neither on human experiences nor technology artifacts exclusively at the expense of the other, but that recognize them as a unifying one in shaping human experiences in a digital world, where human and technology have become so intertwined that we cannot understand one without the other. If our experiences are largely shaped by digital artifacts, IS design research must be *performative* and our research methods should be reflective of it (Law and Urry 2004). Henfridsson and Lingren (2005) offer a fine example of IS scholarship that draws upon design thinking as they endeavor to investigate how to create seamless mobile computing experiences in cars through action research which closely resembles design thinking practice. Their research not only produced theoretical knowledge on the importance of multi-contextuality, but detailed design principles to create desirable user experiences; many of the features are now routinely found in "connected car" platforms.

IS scholars can not only take advantage of design thinking in their own research, they can also advance the intellectual foundation of design thinking. While some design theorists attribute design thinking back to the philosophical tradition of Aristotle and American pragmatist John Dewey (Buchanan 1992), the intellectual foundation of design thinking can be further strengthened by IS scholars . Building on early scholarly works on sociotechnical design traditions (Churchman 1968), our community has a rich theoretical repertoire on sociomateriality, users, digital artifacts, representations, and design processes, just to name a few. Using these theoretical devices, combined with methodological rigor, IS scholars can help design thinking practice by inventing new constructs, models, methods, and instantiations.

Viewpoints on Some Genres of Design Science Research

Intellectual Control of Complexity in Design Science Research: By Alan R. Hevner

Complexity perspective for design science research: Modern enterprises are irreversibly dependent on complex information systems (IS) combining human and technology components whose functional and quality attributes are not necessarily known separately or as an integrated whole. The sociotechnical nature of these systems means that a complete understanding of such systems is difficult or even impossible. A critical question facing design science researchers is how a rigorous discipline can be defined for designing, building, evaluating, evolving, and operating such massive, complex, and unpredictable systems.

The burden of un-mastered system complexity leads to loss of intellectual control when it exceeds human capabilities for reasoning and analysis. Intellectual control means understanding system behaviors at all levels in all circumstances of use. It does not mean the absence of uncertainty—that will always be with us—but rather the capabilities, through engineering and management processes, to deal with it. Thus, a premise of the argument here is that design science must deal effectively with the messy complexity of real IS problems and avoid the reductionism found in much research that simplifies the problem space to one in which known theories and solutions readily apply. Truly new and interesting problems rarely accommodate existing theories and application artifacts easily or exactly.

Limitations of theoretical prediction and the need for adaptive learning in design science research: Simply stated, design science research (DSR) seeks to enhance technology and science knowledge bases via the creation of innovative artifacts that solve problems and improve the environment in which they are instantiated. The results of DSR include both the newly designed artifacts and a fuller understanding of why the artifacts provide an enhancement (or disruption) to the relevant application contexts (Hevner et al. 2004).

Among the key research challenges of the design scientist is how best to ground and to perform the search for a design solution that satisfies the problem constraints (i.e., requirements) while achieving the desired goals (i.e., aspirations and opportunities). The research process supports the simultaneous building of a problem space and a solution space, both of which grow in completeness and evolve through the multiple DSR iterations. The growth in understanding and representational accuracy of both spaces is the long-term objective of a DSR project.

There are two dominant approaches that can be applied during the DSR search process.[1] In rational, stable environments, kernel theories of behavior can be called upon to predict how a particular design artifact will perform in the application environment. A search for a good solution can be planned based on these reliable predictions of IS behaviors. This is the school of *predictive planning* and its success is dependent on the ability to predict the future evolution of the application environment. A second approach moves away from predicting the future and emphasizes adaptive learning based on applying incremental, controlled search methods. The use of non-predictive controls supports a more agile, but riskier, search process that may lead to unsatisfactory ends. This approach is the school of *adaptive learning* and its success is less sure but can be used with problem environments that are fast-changing and have greater amounts of uncertainty.

Given the inherent complexity of current and future IS and the fast-paced nature of change in IS application environments, design scientists will increasingly move away from the limitations of kernel theory predictions to the more adaptive solution search approaches of fast design iterations under the intellectual control of the design team. Extensive search for applicable theories upon which to ground design and predict behaviors is unlikely to be fruitful in complex system environments.[2] It is better for a design team to begin immediately the DSR cycles of building and refining the artifact in a controlled manner. Later, upon reflection of the design results, identification and extension of relevant theories may occur (Gregor and Hevner 2013).

Maintaining intellectual control of iterative DSR cycles: Uncertainty factors capture the unpredictable natures and outcomes of system services. For example, a service may be unavailable, unreliable, incorrect, partial, or compromised, to name a few areas of uncertainty. In addition, multiple services will typically be operating asynchronously and possibly interacting, thereby creating an additional level of complexity. Maintaining intellectual control of the evolving build and evaluate activities in such environments (e.g., Internet of Things, cloud-based computing) requires a design scientist to understand how best to reduce different forms of uncertainty. Drawing from ideas of problem structuring and complexity, two categories of uncertainty can be identified:

- *Reducible Uncertainty*: The problem can be decomposed into sub-problems that can be addressed independently via control techniques of learning, bounded scope, abstraction, rapid stakeholder feedback, and composition of solutions.

- *Irreducible Uncertainty*: The problem has no obvious decomposition and must be solved as a whole via control techniques like scenario generation, simulation, and risk reduction. However, big problems are often perceived to be irreducible because they are not well understood.[3] The solution approach then must first attempt to gather more facts in order to better understand and represent the problem in a way to support decomposition.

A major challenge in problem structuring is differentiating between these two situations and then applying the most effective controls in order to iteratively refine a design artifact to the point that it is ready for introduction into the application environment. This process of design iteration and refinement asks the following key control questions:

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[1] These two search approaches can be found across many disciplines, including strategic management (Brews and Hunt 1999), entrepreneurship (Wiltbank et al. 2006), and software engineering (Harris et al. 2009).

[2] "Whenever a theory appears to you as the only possible one, take this as a sign that you have neither understood the theory nor the problem which it was intended to solve," Karl Popper, *Objective Knowledge: An Evolutionary Approach*, Oxford, UK: Oxford University Press, 1972.

[3] "The bigger the problem, the fewer the facts," Harlan Mills, personal communication, ~1986.

- *Have we rigorously captured the complexities of the problem in order to evaluate the goodness of the design solution?* The design of fit and sustainable solutions requires that we move beyond well-known usefulness criteria to the evaluation of more challenging fitness characteristics such as novelty, openness, and elegance (Gill and Hevner 2013).

- *Is the design feasible?* Can the proposed design be implemented and does the proposed design meet the basic problem requirements?

- *Does the design have value?* Does the design offer benefits unmatched by competing candidate designs? Here the objective becomes to establish an ordinal valuation that can be used to rank candidate designs based on key goodness criteria.

- *How can the design be most effectively represented?* How can we best communicate the intricacies of the design to collaborators, implementers (e.g., architects, programmers), and other stakeholders? As examples, a blueprint is a representation artifact that serves to guide the physical construction of a house; source code is a representation artifact that serves to generate the software programs that are distributed to users.

- *How best to construct the actual artifacts for use?* How do we guide the construction of the use artifact within the real-world constraints of the application context?

The iterative design cycles of DSR support refinement of the artifact in ways that answer these questions while simultaneously generating new knowledge of the problem space and solution space of the research.

In summary, the complexity of real-world design problems and opportunities often precludes the ready identification of grounding theories to support predictive planning. Instead, the design scientist must have the skills to apply control techniques of adaptive learning via iterative design cycles to grow a satisfactory artifact that meets the fitness and sustainability requirements of the problem environment. Thus, the DSR mantra is "Just Build It!"[4]

Computational Genre of Design Science Research: By Hsinchun Chen

Fundamental premise and key scholarly quests: The fundamental premise of computational design science is impact and relevance. It emphasizes an interdisciplinary approach in developing novel data representations, computational algorithms, business intelligence and analytics methods, and human–computer interaction (HCI) innovations, and holds great potential for generating IS research with significant business and societal impact.

In the National Research Council of the National Academies report "Assessing the Impacts of Changes in the Information Technology R&D Ecosystem: Retaining Leadership in an Increasingly Global Environment" (2009), the IT R&D ecosystem includes much government-sponsored, high-impact (as measured in terms of job and wealth creation) IT R&D, from the earlier years of client/server computing and workstations, to the more recent successes in web-based technologies (e.g., search engines, social media, and e-commerce systems) and data analytics. Each success case can be attributed to selected initiating universities or departments, subsequent commercialization and industry R&D, and the resulting billion-dollar market. Although many of these earlier IT successes have been attributed to computer science, there are significant opportunities for IS scholars to lead in developing novel solutions for critical problem domains and significantly advancing IS knowledge.

Exemplar articles from the IS literature: We have begun to see computational design science research in high-impact problem domains published in *MIS Quarterly* and other IS outlets over the past decade, for example, social media analytics and cybersecurity (Abbasi and Chen 2008; Abbasi et al. 2010) and health analytics (Lin et al. 2017).

Abbasi et al. (2010) (referred to here as AZProtect, winner of the 2010 *MISQ* Best Paper Award) and Abbasi and Chen (2008) (referred to here as CyberGate) in particular

[4]With acknowledgments and apologies to Nike and the movie, *Field of Dreams*.

- Develop a novel computational framework that is inspired by relevant theories (e.g., systemic functional linguistic theory).

- Provide good illustrations of careful and comprehensive data and feature representations via advanced text analytics (web page text, URLs, source code, images and linkage features for AZProtect; lexical, syntactic, semantic, and structural features for CyberGate).

- Contribute to machine learning methods (linear composite SVM kernel for fake website detection for AZProtect; principal component analysis and decision trees based text classification for CyberGate).

- Illustrate the development of working prototype systems (AZProtect and CyberGate) for evaluation, including novel and intuitive text visualization.

- Have been adopted in real-life e-commerce and cybersecurity applications with partners of the University of Arizona and the University of Virginia.

Lin et al. (2017) contribute to health analytics by introducing Bayesian multitask learning for chronic care, which coordinates and learns from multiple health events. The research also adopts a highly relevant counterfactual analysis approach that considers practical clinical use.

Key misunderstandings of authors and reviewers: Two common misunderstandings are seen among IS authors and/or reviewers regarding computational design science research.

- *Where is the theory?* Although "development of design theory" would be considered a contribution to IS knowledge, much of computational design science research does not require a theory. However, demonstration of design novelty (in representation, algorithm, analytics, and HCI) and validity (in lab and field evaluation) for critical applications are needed. Such research can often benefit from presenting a comprehensive and logical computational or system framework (still not a theory, but a framework that is informed by relevant theories and problem domain perspectives), as demonstrated in selected prior computational design science research (Abbasi and Chen 2008; Abbasi et al. 2010).

- *Does this fit a boilerplate?* Due to the evolving nature of emerging applications and the novelty requirement for computational techniques, computational design science research may not fit a traditional boilerplate. Type II reviewing errors (rejecting an exciting but unusual paper that the community would have welcomed) may occur if the review of novel and exciting work is approached with a restrictive imposition of boilerplates.

The IS community has an opportunity to significantly broaden its perspectives in applications (from traditional business domains to broader societal problems) and computational approaches (from well-known statistical analysis methods to other novel algorithmic and analytics techniques) in order to develop high-impact design science research in the future.

Some exciting new directions: As a highly interdisciplinary discipline, the IS community benefits from its academic roots in organizational behavior, management, economics, management science, and computer science; however; significant adaptation and advancement should also result from IS research. Compared with computer science (which is often more fundamental, computer-centric, and programming oriented), computational design science offers a unique information-centric, domain-driven, and interdisciplinary approach. Looking ahead, there are some exciting new research areas and new directions for the design science community.

- *Data representations*: Most critical applications, from finance and e-commerce to health IT and cybersecurity, are highly information centric and domain specific. While database management systems, data warehousing, and NoSQL can facilitate data processing, the tasks of identifying, extracting, and creating relevant and comprehensive features, variables, or attributes for the often unstructured, complex, and high velocity/volume/variety/veracity data requires significant domain knowledge and careful feature engineering. Computational linguistics, image processing, and mobile processing research are critically needed for many emerging information-rich applications.

- *Computational algorithms*: Computational algorithms—from fundamental searching and sorting methods to advanced and continuously evolving optimization, stochastic search, genetic algorithms, and reinforcement learning methods—will continue to play a significant role in computational design science research. Diverse, transformative, and novel algorithm development and validation (versus state-of-the-art benchmark methods) are needed, especially for new and emerging applications in e-commerce, health, and security.

- *Business intelligence and analytics*: A unique class of analytical computational algorithms has recently received significant attention from both academia and industry. Leveraging big data, cloud infrastructure, and parallel computation, business intelligence and analytics (BI&A) research (Chen et al. 2012) calls for advances in (big) data analytics, newer text analytics, web analytics, network analytics, and mobile analytics areas.

- *Human–computer interaction*: In addition to the more foundational and data centric representation, algorithmic, and analytics research, IS scholars can use computational design science to focus on more user- or human-centric HCI research, including information visualization, interface design, and human factor studies. Such research often calls for an interdisciplinary team of computational, design, and behavioral scholars. Extensive lab and field-based HCI experiments are needed to confirm the validity, value, and impact of the proposed algorithmic and system design.

In conclusion, in light of the recent trend in big data/computation and "AI awakening," the IS community would benefit from adopting the emerging big-data and big-computational open-source platforms available to the broader IT community, from Hadoop and Spark (for parallel data processing and computation), to statistical machine learning and the resurgent artificial intelligence-based deep learning methods. The combined effect of advanced analytics, big data, and parallel computation promises to bring an exciting future for developing high-impact research that would amplify the R&D work of many other research streams. Young and emerging design science scholars might find these directions to be especially interesting, and progress in these areas could be of enormous and long-standing benefit to society at many levels.

Optimization Genre of Design Science Research: By H. Raghav Rao and Sumit Sarkar

Key premises and scholarly quests: A central goal of design science research is the creation of IT artifacts intended to solve problems being faced by organizations (Hevner et al. 2004). The ability to create sophisticated artifacts is typically predicated by the ability to develop a formal model of the problem instance(s). As organizations and other entities try to achieve their goals (e.g., maximize profits, utilities, welfare, etc.), optimization and related techniques are well-suited to help them make IS design choices that best support those goals.

Optimization techniques provide a rigorous framework to model many business and societal problems (and processes) impacted by emerging information technologies. These techniques can be used to design and implement IS solutions to improve and/or innovate upon existing (often *ad hoc*) processes impacting how an entity operates to create value. This includes opportunities to optimize, for example, a firm's supply chain activities (e.g., increasing visibility of inventories), internal operations (e.g., establishing appropriate cyber security assurance policies), customer relationship management activities (e.g., the effective use of personalization technologies), pricing decisions (e.g., price discrimination strategies enabled by IT), etc.

In addition to optimization (mathematical programming) formulations, there are closely related approaches that do not adopt a strict optimization approach but instead use other modeling techniques (such as using decision theoretic techniques, simulations, etc.) where heuristic algorithms or procedural frameworks are developed. Modeling and simulation artifacts can be especially useful for decision support in dynamic problem environments (e.g., in public health or emergency response contexts) where problem instances are too complex to specify and solve comprehensively in an optimization framework.

In summary, this genre of design science research uses optimization and related modeling approaches to propose prescriptive solutions to change the way information systems function (e.g., by designing, modifying, or constructing systems) so that they can better solve real-world problems.

Major types of scholarly contributions: Typical contributions involve identifying novel decision problems related to IS that can be cast in an optimization framework, and then solved using extant solution techniques or adaptations of extant techniques as dictated by the problem context. Contributions can be theoretical, for instance identifying important characteristics of optimal solutions which can be used to design algorithms. Contributions may involve demonstrating, based on experiments in real-world or simulated environments, the efficacy of the proposed solution techniques in achieving the objectives of the systems. Conditions under which the solutions are best realized, or where they may be compromised, could be part of the contribution.

Selected exemplar articles: Recent works involve investigating diverse problem domains in which IS is salient in generating innovations and improvements and using a range of optimization methodologies to identify optimal solution characteristics. Although there is diversity across domains and methodologies, a common schema is often present in these works.

- *Framing the problem in a manner where key design decisions are formulated as an optimization problem*. Menon and Sarkar (2016) model the problem of hiding sensitive data (patterns) in transactional databases as an integer program that reduces to the set covering problem. Sen and Raghu (2013) focus on optimal incentive design for outsourcing IT infrastructure services by using process modeling to identify interdependencies among IT services, and a multitask agency theory to formulate how incentives can optimally manage the interdependencies. Chaudhury et al. (1995) use a mixed integer programming model that incorporates participation and truth-telling while inducing outsourcing vendors to submit their most competitive bids.

- *Identifying important characteristics of optimal solutions*. Dawande et al. (2012) identify, when searching for an influential set of nodes in a social network, special network structures which enable efficient solution techniques. Ghoshal et al. (2015) show how finding the best combination of rules when making product recommendations in e-commerce environments is equivalent to finding the set of nonoverlapping rules that lead to the highest sum of mutual information terms associated with them.

- *Develop algorithms or heuristics based on the characteristics of solutions*. Dawande et al. (2012) develop optimal algorithms for several important network structures, while Ghoshal et al. (2015) develop heuristics to solve the rule combination problem in real time.

- *Evaluate the efficacy of the proposed methods*. Fang et al. (2013) conduct experiments on simulated data to demonstrate the effectiveness of their Markov decision process based solutions, while Menon and Sarkar (2016) use both real-world archival data as well as simulated data to demonstrate the effectiveness of their recommendation methodology.

Some exciting areas for future research: The steady proliferation of new technologies continuously changes the way businesses operate, leading to new processes involving these technologies. The digitization of such business processes result in enormous amounts of data collected at source. As a result, analytics has become one of the hottest areas of research and practice. To best leverage the intelligence inherent in the available data, optimization techniques should play an important role. Topical domains include, among others, smart city initiatives and the Internet of things.

With increasing economic and social activity occurring in digital contexts, noneconomic considerations are becoming salient considerations in identifying the optimal design of IS solutions. For instance, one such consideration is the trustworthiness of systems—that is, guaranteeing no harm will happen even under conditions of hazards such as design errors, physical failures, and erroneous interactions among users, nor under disturbances or extreme events (Sifakis 2014).

Key misunderstandings of reviewers and authors: Some reviewers take guidelines in Hevner et al. (2004) to evaluate design science research too literally. For instance, while Gregor and Hevner (2013) explicitly recognize that the evaluation of design science research contributions may be flexible, and could involve analytics, experiments, or simulations, reviewers sometimes ask for evaluations using implementations in real environments that is overly onerous for researchers. Further, the innovation required in transforming an IS problem, for example, finding the best set of rules to combine in Ghoshal et al. (2015), into a suitable optimization formulation (i.e., a set partitioning problem), can be challenging in its own right and may itself represent a key contribution.

Representation Genre of Design Science Research: By Andrew Burton-Jones and Jeffrey Parsons

Fundamental premises and key scholarly quest: The fundamental premises of research in this genre are that

(1) a more "effective" information system will result if the model underpinning an information system faithfully represents stakeholders' perceptions of phenomena in the domain of interest than if it does not; and

(2) maintaining this faithfulness through a series of scripts (from a conceptual model to an implemented system) is central to building effective systems.

The key scholarly quest is to design and validate modeling grammars (i.e., constructs and rules for creating meaningful scripts; statements about a domain), scripts (i.e., models of domains expressed as statements adhering to a grammar), or methods (i.e., how to use grammars to create scripts) that will facilitate the faithful representation of perceived domain phenomena in information systems.

As would be expected in any mature field, there are healthy debates on these issues. In particular, although most researchers in this genre agree on the criticality of faithful representations, some argue that this is not enough, because it focuses too much on the descriptive aspect of language and not enough on the performative aspect (Ågerfalk 2010). Researchers who ascribe to this view have made key contributions by (1) identifying the limitations of concentrating solely on representational faithfulness, and (2) demonstrating the importance of the performative perspective.

Major types of scholarly contributions: The major types of contributions in this genre include (1) the evaluation and refinement of existing modeling grammars or methods (Wand and Weber 1993), or the design of new modeling grammars or methods (Tillquist et al. 2002); (2) the development of software artifacts to support or instantiate such work (e.g., Purao et al. 2003); and (3) the evaluation of these efforts using analytical methods (Clarke et al. 2016), or inductive (Hadar and Soffer 2006) or deductive (Recker et al. 2011) empirical methods.

A common characteristic of these contributions is that they involve traversing challenges from philosophy, linguistics, and psychology that inevitably arise when studying representations. Also, as representations are designed by and for humans, evaluations often involve humans. Because of these challenges, theory plays a key role, both in designing modeling grammars and in predicting the effects of modeling constructs on effective use (Weber 1987). It is not a genre in which meaningful progress can be made easily by assuming away difficult theoretical issues or human participants.

Exemplar studies in the representation genre: We highlight two studies that differ according to the views noted above. The first study is Wand and Weber (1993). It showed how a theoretical perspective that was new to IS at that time (ontological theory) could help guide the design and evaluation of conceptual modeling grammars. Two features of this article made it an exemplar. First, it provided a *theory* that researchers could use to underpin their work. This filled a need due to the predominantly practical and empiricist approach that prevailed at that time. Second, the article offered a parsimonious and understandable set of concepts. As a result, the concepts became widely used in subsequent research published in top IS journals, including in *MIS Quarterly* (e.g., Bera et al. 2011; Recker et al. 2011).

The second study is the book by Stamper (1973). This book provided a semiotic perspective on information systems and offered a new way to think about information systems development and evaluation. It is an exemplar because it was one of the earliest detailed treatments of the nature of information, offering a potential foundation for much IS research. Also, Stamper benefitted from having a relevant context in which to illustrate his ideas (the design of legal systems). Over time, the ideas were developed further, but they were often published in non-mainstream outlets rather than top IS journals. The ideas are still being developed, but rather than being used directly by IS researchers, they tend to serve as an inspiration (Ågerfalk 2010).

These two contributions are similar in that (1) both appeared in outlets that allowed the researchers some leeway in publishing their ideas at the time, and (2) the actual contributions depended on programmatic work over subsequent years. Both contributions were ahead of their time and they also offer interesting lessons for how to sustain contributions over the long run.

Key misunderstandings of reviewers and authors: The first common misunderstanding is that conceptual modeling equates to data modeling. Even though researchers sometimes treat these concepts similarly and use overlapping terms (e.g., conceptual data modeling), they are distinct. Conceptual modeling involves representing a real-world domain, as perceived by stakeholders (Wand and Weber 1993). Data modeling involves describing data for the purpose of understanding or designing a database. Data modeling tends to assume an implementation approach, even if implicitly; conceptual modeling frees researchers from this constraint (Parsons and Wand 2008).

The second misunderstanding is that design science articles in this genre must follow an explicit design science template or recipe (e.g., based on the the criteria in Hevner et al. 2004). We have been told by reviewers to rewrite our articles accordingly. However, research in this genre is older than the design science literature. In fact, all of the authors of the well-known Hevner et al. (2004) paper made contributions to the representation genre *before* they wrote that paper. And the exemplar studies above were also written much earlier. Thus, while we support and value research on design science, good articles in the representation genre need not follow any particular design science template or recipe. To many researchers in this genre, science is science; the "design science" label plays a valuable legitimizing function, but good work of this genre has been performed, and continues to be performed, without it.

The third misunderstanding is that this topic may lack relevance for today's contemporary environments. In fact, the reason why many researchers are excited to work on design science in the representation genre is that we believe we are contributing to the essence of information systems. Technologies and applications come and go, but representational issues remain. The key is to understand which representational issues are salient and why (Lukyanenko et al. 2014).

Some exciting new directions: The most exciting directions are those that tackle *both* fundamental issues and new practical problems. For instance, one of us has been excited by the challenge of modeling in new application environments (such as crowdsourcing) in which requirements are unknown and changing. This is an exciting area because solving the practical issue also involves tackling fundamental issues of representation (e.g., modeling instances vis-à-vis classes) (Lukyanenko et al. 2014).

Likewise, another one of us has been studying challenges in specific industries. For instance, in healthcare, a challenge is maintaining high-quality data at the instance, part–whole, and class levels, as different users are interested in different levels (Burton-Jones and Volkoff 2017). This is an exciting area because solving the practical issue involves tackling a fundamental issue (conflicts between levels).

Finally, due the changing nature of commerce and work, both of us are interested in opportunities for greater attention to geospatial and temporal modeling. Once again, this is an exciting area because of its relevance for new applications, but also because it touches on fundamental representational issues of space and time (Currim and Ram 2012).

IS Economics Genre of Design Science Research: By Alok Gupta, Wolfgang Ketter, and Arun Rai

Key premises and scholarly quests: In an expanding array of problem domains in which economic considerations are salient, decision makers' preferences are challenging to capture and may be unknown to them, decisions are interdependent with decision rights distributed across agents, and choices are combinatorial. Advances in information technology are redefining the information generation and processing capabilities of decision-making environments and are providing new ways to execute and organize economic activities. For example, there is an expanding array of IT functionalities to observe events and states, monitor and control behaviors, coordinate activities and decisions, organize and protect resources, learn from experiences, and generate real-time intelligence. These IT functionalities are creating opportunities to envision new business models and ways to design novel mechanisms to organize and execute economic activities. They are also falsifying assumptions and leading to a breakdown of classical economic theory predictions on the design of mechanisms to execute economic activities and achieve the objectives of economic systems.

The IS economics genre of design science focuses on (1) understanding how IT functionalities can enable the design of mechanisms for the conduct of economic activities and the attainment of objectives of economic systems in which they are embedded, and (2) design of IT-based artifacts (e.g., control mechanisms, feedback mechanisms, predictive models) that explicitly account for the economic characteristic of the environment in which they operate. Given the potential for IT to fundamentally affect an expanding set of economic activities including decision making, organization of resources and activities, and economic exchange in a range of problem domains, studies exhibit rich variety in the scope and types of economic activities that are examined.

In addition to theoretical perspectives from information systems, the development and refinement of solutions are typically informed by (1) theories in economics and behavioral disciplines, (2) algorithmic techniques in operations research, computer science, statistics, and other disciplines, and (3) feedback from contexts in which the solutions are evaluated.

Major types of scholarly contributions: The major types of contributions include (1) development and refinement of models and algorithms that focus on the role of IS to solve problems related to the conduct of economic activities and attainment of objectives of an economic system; (2) discovery and characterization of behaviors of economic participants; (3) instantiation of models and algorithms into software, technology platforms, and other artifacts; and (4) evaluation of the validity of causal mechanisms *and* the utility of solutions.

Studies contribute to the understanding of how and why the heterogeneity of the contexts in which a solution is used affects its performative aspects because of interactions between technology, user, task, and policy regimes. This understanding enables improvements of the solution and elaboration of theoretical underpinnings on the relationship between IS and the design of economic systems.

Selected exemplar articles: We present a few examples to illustrate the emphasis in this genre on the distinctive economic characteristics of the environment, the informing role of relevant economic and behavioral theories, and the use of a variety of algorithmic approaches to develop IS solutions to problems in diverse domains.

Looking at the problem of scheduling resources to manage a real-time database where users are delay sensitive, Konana et al. (2000) model the real-time database environment as an economic system. They design a query management system based on real-time pricing of computing resources and use a simulation approach to demonstrate the performance advantages of this economics-based mechanism relative to traditional database scheduling techniques.

Focusing on the sequential and discrete nature of multiunit Internet B2C auctions that render the traditional analytical framework of game theory intractable, Bapna et al. (2003) develop a simulation model for jointly exploring the combinatorial space of design choices of auctioneers and the bidding strategies that can be adopted by the bidders. The simulation model was informed by the theoretical revenue generating properties of these auctions and validated using real-world auction data.

As an example of how behavioral perspectives inform the design of IT artifacts that are embedded in economic systems, Adomavicius et al. (2013) focus on the distinctive characteristics of continuous combinatorial auctions to identify different but theoretically isomorphic real-time feedback schemes for bidders. They hypothesize the relative performance effects of the feedback schemes and evaluate their predictions using lab experiments.

As a final example, Ketter et al. (2016) develop a competitive gaming platform to discover how IS innovations can be used to design sustainable energy systems. The design of the platform and its processes are informed by the economic characteristics of the energy market and theories related to mechanism design. The platform uses computational tools and methods to integrate a variety of data (e.g., consumer usage, production, regulation) and generate information to assess operational strategies and regulatory regimes. Research groups from around the world compete on the platform to devise, benchmark, and improve IS innovations for the energy system.

Some exciting areas for future research: There are exciting research possibilities at different levels including markets, firms, business models, decision processes, and policy analysis.

Future work can examine how IT functionalities can be used to design economic systems to solve problems in markets and trading environments for a variety of goods and services (e.g., energy, healthcare, piracy of digital goods). Studies can investigate how interdependencies in design decisions at different levels (e.g., policy, trading platform, location) can be redefined through IT and the implications for the functioning of market-based environments from both operational as well as policy perspectives.

With the Internet now as a platform for computing and economic activities, there is the need to bring together economic, behavioral, and computational perspectives to understand how to design innovative platform-based business models. Understanding these opportunities requires simultaneously examining how traditional considerations (e.g., incentive compatibility from mechanism design and bounded rationality from a behavioral perspective) can be combined with coordination choices (e.g., distribution of information, agents, computational models) and algorithmic advances to achieve computational tractability.

From an evaluation and learning standpoint, research positioned at the intersection of platforms, big data, agent-based systems, and behavioral modeling provides unique opportunities to test counterfactuals related to economic design interventions which otherwise would be complex or infeasible to assess.

Key misunderstandings of reviewers and authors: Reviewers sometimes rigidly apply evaluation criteria for design science research. Guidelines to evaluate design science research (e.g., Hevner et al. 2004; Gregor and Hevner 2013) should be applied with consideration of the objectives, the choices of theories and methods, and contribution of a study.

Although construction of an artifact (e.g., designing or adapting an algorithm to solve a problem) is an important step, the economic systems that are enabled by IT may address novel phenomena that emerge due to affordances provided by new technologies, a redefined economic environment, and the availability of a rich set of structured and unstructured data. Researchers often need to think in terms of evaluating systems as a whole and not only in terms of evaluating individual IT artifacts.

Observations on Commonalities and Differences Across Genres

The perspectives expressed in this editorial surface insights on the diverse and sustained contributions to design across the IS community and on the commonalities and differences across genres of design science research, as I briefly discuss.

Diverse and sustained contributions about IS design: Design has been a central concept through the history of IS scholarship. Over the last four decades, significant progress has been achieved in our knowledge about IS design in a number of areas such as conceptual modeling (e.g., representation methods and grammar), systems development (e.g., how systems should be designed to be adaptive to high requirements uncertainty), human–computer interfaces (e.g., information visualization to manage cognitive overload), decision making (e.g., design of recommendation systems for e-commerce and mobile commerce), collaboration (e.g., design of group support and workflow systems), and economic exchange (e.g., design of mechanisms for dynamic pricing in online environments). This breadth of progress has been achieved through the use of diverse theories and methods to inform the development of IS solutions and to address fundamental questions related to IS design and its role in wide-ranging problem domains.

Common characteristics across genres of design science: The viewpoints surface two commonalities across the genres of design science: (1) the overarching quests and contributions and (2) the general nature of the search process.

Overarching quests and contributions: The viewpoints on the different genres of design science surface two overarching common quests and corresponding types of contributions: (1) developing and evaluating solutions that can be introduced as design interventions to improve the state of affairs in the real world (expressed by terms such as utility, performative, and business and societal impacts) *and* (2) adding to knowledge about IS design and the role of IS design in problem domains (expressed by terms such as validity, models and algorithms, scientific and technical knowledge, theory).

General nature of the search process: The viewpoints reveal common characteristics across genres of design science in how search processes for solutions are executed, and include:

- Focusing the search on clearly defined, well-motivated objectives and salient IS characteristics for the creation of novel design interventions (e.g., methods, models, algorithms, heuristics, systems).

- Predicating the search on (implicit) assumptions about the interdependence between IS and the phenomenon and the types of uncertainty underlying the phenomenon that the researcher seeks to address.

- Directing the search through consideration of (1) the role of selected or constructed theories in formulating and solving problems and in informing the creation of the design artifacts, and (2) the role of selected or developed methodologies in formulating and solving problems and in informing the creation of the design artifacts.

- Evaluating the validity and utility of the novel solutions in different contexts and discovering contingencies and boundary conditions.

It is noteworthy that these common characteristics across genres of design science are similar to those expressed in related perspectives and methods that present approaches to search for design interventions to address problems in business and societal contexts. These include methods to integrate design science and action research perspectives (Sein et al. 2011) and more broadly the engaged scholarship perspective (Van de Ven 2007). In addition to generating solutions, these perspectives and methods are also oriented to making contributions to theoretical knowledge about design and the problem domains.

Diversity across genres of design science: It is interesting to observe the range of diversity across (and within) genres of design science in two notable areas:

- *What is designed and evaluated?* There are significant differences across genres in what artifacts are designed and evaluated, for example methods and grammars (representation genre); computational algorithms and methods (computational genre); optimization solution techniques, models, and algorithms; heuristics algorithms and procedural frameworks (optimization genre); and mechanism design artifacts (e.g., control mechanisms, feedback mechanisms, predictive models) that explicitly account for the economic characteristic of the environment in which they operate (IS economics genre).

- *How the search process is configured?* Despite similarities in the general considerations for the search process for solutions, the various genres (and studies within genres) vary significantly in how they formulate problems, inform artifact design, and evaluate solutions because of *choices within,* and *combinations across,* the following elements:

  – Theories (one or more preexisting theories or a constructed theory), with implications for assumptions, focal constructs and relationships, and boundary conditions.

  – Methodologies (e.g., optimization, computational, statistical), with implications for how the problem is cast to align with the requirements of the methodologies.

  – Modes of evaluation (e.g., simulation, real-world experiments, role of human subjects, the specific social context, etc.), with implications for how validity and utility of solutions is assessed, contingencies are surfaced, and feedback is generated for solutions to be refined.

Given this variety, the issue of a single script being too restrictive for conducting and assessing design science research is salient in the viewpoints of the various genres expressed in this editorial.

Concluding Remarks

The purpose of this editorial is to present a diversity of perspectives related to design and across some genres of design science research in the IS community. Clearly these genres are neither exhaustive nor are they mutually exclusive, but the viewpoints surface important commonalities and differences across genres of design science as well as opportunities for IS research.

As design is concerned with creating a world that *might* be and is preferable over the current state, search approaches—involving conventional and innovative theories, methodologies, and evaluation modes, and their novel combinations—can play an important role in developing IS solutions and significantly advancing our knowledge about IS design and its role in problem domains. *MIS Quarterly* welcomes such research that achieves impact by solving problems *and* contributing to the accretion of scientific IS knowledge related to theories, problems, or methods.

Retiring and Incoming Editors

I would like to thank the following individuals who completed their terms on the editorial board in December 2016 for their valuable service:

> **Senior Editors**: Ravi Bapna (University of Minnesota), Kai Lim (City University of Hong Kong), Sue Newell (University of Sussex), and Youngjin Yoo (Case Western University)
>
> **Associate Editors**: Geneviève Bassellier (McGill University), Angelika Dimoka (Temple University), Yulin Fang (City University of Hong Kong), Robert Fuller (University of Tennessee), Wolfgang Ketter (Erasmus University), Liette Lapointe (McGill University), Gal Oestreicher-Singer (Tel Aviv University), Stacie Petter (Baylor University), Saonee Sarker (University of Virginia), and Huimin Zhao (University of Wisconsin, Milwaukee)

In addition, I am delighted to welcome the following individuals to the editorial board:

> **Senior Editors**: Brian Butler (University of Maryland), Gerald Kane (Boston College), Saonee Sarker (University of Virginia), James Thong (Hong Kong University of Science and Technology), and Siva Viswanathan (University of Maryland)
>
> **Associate Editors**: Nicholas Berente (University of Georgia), John D'Arcy (University of Delaware), Xiao Fang (University of Delaware), Pedro Ferreira (Carnegie Mellon University), Hong Guo (University of Notre Dame), Shuk Ying (Susanna) Ho (Australian National University), Eivor Oborn (University of Warwick), Jui Ramaprasad (McGill University), Diane Strong (Worcester Polytechnic Institute), Anjana Susarala (Michigan State University), Juliana Sutanto (Lancaster University), and Xinlin Tang (Florida State University)

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