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**Editorial**

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# Smart designing of smart systems

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We live in an age when previously disjunctive concepts, theories, methodologies, technologies, implementations, applications, and cultures are coming together. This does not mean a reductionist integration but a holistic synthesis of the abovementioned things. This widespread phenomenon is often referred to as convergence, which may happen in multiple forms across multiple domains. Examples include forming a transdisciplinary scientific discipline, amalgamating hardware, software, and cyberware in complex systems, interplaying social demands and technological affordances, and merging massive data, information, and knowledge. Convergence influences not only physical but also cognitive processes. Fueled by the results of artificial narrow and general intelligence, the physical, perceptive, and cognitive capabilities of humans and intellectualized engineering systems are also converging. This rapidly proliferating trend of convergence provided theoretical underpinning for this thematic collection and explains its practical relevance. In this case, convergence concerns the approaches and methods of smart designing and the development of smart systems, and is facilitated by various manifestations of artificial intelligence (AI) enablers.

There were two sources of papers that contributed to this thematic collection. First, several papers were based on the best papers of the *Thirteens International Symposium on Tools and Methods of Competitive Engineering* (TMCE 2020). The selected papers were reworked and extended with additional research results and findings. The other papers were contributed based on the Call for Papers proposed by the guest editors. All papers were critically reviewed and revised by the authors before their acceptance for publication. The papers included in this thematic collection cover critical specific aspects of smart design, smart systems, and smart designing of smart systems. Altogether eight papers are included, which offer novel theories, methods, working principles, system functions, and smartness enablers. They reflect a reasonable coherence and complement each other.

The first paper, entitled *Connectors of smart design and smart systems*, is a position paper that discusses the backgrounds and proposes an interpretation of the concepts of smart designing and smart systems, respectively. Contributed by Imre Horváth, this paper also proposes a reasoning model concerning the relationship between smart designing and smart systems. It is argued that the progression toward smart designing and smart systems has been triggered and enabled by the recent advances in AI research and development. The author provides an interpretation of the concept of smartness and an overview of the characteristics of smart design as an AI-supported creative problem-solving methodology. The paradigmatic features and system engineering issues of smart systems are also discussed. The genuine contribution of this position paper is a conceptual model of AI-based couplings of smart designing and smart systems, referred to as "connectors." Examples of the principal types of connectors are given. It is shown that smart design tends to manifest as an approach of blueprinting smart systems, whereas smart systems are used as intellectualized enablers of the implementation of smart design. The identified primary connectors, as AI-based enablers, hint at forms and methods how smart designing may be associated with smart systems in practice.

In the second paper entitled *Smart design of intelligent companion toys for preschool children*, Xin Wang, Nian Yin, and Zhinan Zhang put forward a complete process to smartly design and update the smart companion toys for children, which is user-centered and environment-oriented. As a smart system, the smart companion toy takes children's cognition and emotion as the core consideration to provide a more natural and exciting interactive experience. Simultaneously, it coordinates the development of children's multiple senses at every stage. The entire design process is divided into three main parts, which are requirement confirmation, collaborative design, and iterative updates after the sale. Requirement confirmation is completed via demand collection, authenticity, and prioritizing. Before sale, the design process can be divided into input, analysis, function, output, user interface, evaluation, and testing, all of which are collaboratively completed by humans and AI. After being put into use, the smart iterative update process is completed through interaction with users and the environment with local processors and the company cloud. Under the framework proposed in the first paper, the companion system's smartness is demonstrated through the smart, collaborative design process enabled by "connectors" such as graphics-based modeling, simulation, optimization, and user behavior mining.

Specification of functions is an important part of the systems design process, which converts the requirements and constraints into feasible operation principles, function carriers, and architectural arrangements. The authors of the third paper, Fajun Gui and Yong Chen, recognized that traditional approaches of functional design do not adequately take into account the interactions between a smart system under development and its environment, and cannot explicitly represent the complex functional logic of the system in software engineering. This motivated their research, the results of which are presented and discussed under the title *A scenario-integrated approach for functional design of smart systems*. The paper explains how to employ scenarios to express subjective customer needs and how to generate the functional architectures and derive the corresponding solution concepts through a structured process. The benefits of the proposed approach are demonstrated through an application example that concerns an automated doors-unlocking sub-system of a smart vehicle. The proposed scenario-integrated approach creates a coupling between the most decision-intensive phase of designing and the smartness-increasing functionality of software systems, and can be used in other application contexts.

The fourth paper reports the research work and results of Jie Pan, Jingwei Huang, Yunli Wang, and Yong Zeng, entitled *A self-learning element extraction system by reinforcement learning*. This paper offers a novel approach to the automatic generation of high-quality meshes that is a kernel activity of computational analysis and simulation. By applying some original theories and powerful technologies of artificial narrow intelligence, it converts the traditionally numerical computation-based approach into a cognitive computation-based approach. It increases the smartness of the computational process by using element extraction rules and provides better quality meshes, particularly in the vicinity of domain boundaries. Enabled by the A2C reinforcement learning network and the self-learning feedforward neural network, the proposed element extraction system, FreeMesh-S, represents a smart system, which works according to a smart element design and extraction strategy. Using the language of the first paper, we can say that it connects smart design to a smart system through the automatic self-learning schema. This paper has two merits. First, while there are still a few limitations, the proposed system provides better results than that can be achieved by conventional numeric calculation- or artificial neural network-based approaches in the case of quadrilateral mesh generation. Second, it provides a demonstrative example of using application-oriented knowledge to create a connector between smart designing and a smart system for researchers working toward comparable objectives.

Rapidly proliferating in the making industry, digital platforms are business-enabler means concerning value-creating interactions between producers and consumers. Their value generation and impacts are analyzed based on various business models. As conceptual and cognitive enablers, business models have actually become an integral part of knowledge-intensive systems design processes. The paper contributed by Patrick Brecht, Manuel Niever, Roman Kerres, Anja Stroebele, and Carsten Hahn addresses a related critical activity, which is the validation of business models. The paper entitled *Smart platform experiment cycle – A process to design, analyse and validate digital platforms* intends to increase the smartness of the platform design process by including a business model validation cycle. The proposed experiment cycle collects additional business information and integrates it with other chunks of information that are used at making decision about the economic prospects of development initiatives. The basis of this methodological work is formed by the principles of design science research. The proposed process is decomposed into five steps, which focus on business model conceptualization, designing experiments, developing design experiments, running and measuring the experiments, and analyzing and learning from the results. It was investigated in the case of a startup company, which works according to a digital platform business model.

As smart designing and smart systems have a bijective relationship, the system resources will have to support multiple tasks related to making designing smart and realization of the smartness of systems. Autonomous resource allocation must be improved to make efficient use of the limited resources of the developed system. In the case of the sixth paper entitled *Autonomous resource allocation of smart workshops for cloud machining orders*, coauthored by Jizhuang Hui, Jingyuan Lei, Kai Ding, Fuqiang Zhang, and Jingxiang Li, the system is a production workshop. The paper proposes a multi-objective optimization model for the allocation of workshop collaborative resources (MOM-WCR). Enabled by an improved firefly algorithm, the MOM-WCR is applied in the context of cloud manufacturing to the considered smart workshop. The paper introduces a collection of decomposition rules for cloud machining orders, including hierarchical decomposition principle, granularity control principle, and coupling principle. As connectors, this rules-orientated approach connects the smartness of designing to the smartness of system operation. The problem formulation and solution principles can be taken as a lesson for resource allocation in other smart systems.

Managing rules plays an important role also in the seventh paper included in this thematic collection. A critical characteristic of smart systems is to learn from their own experiences. Wenbin Zhou, Xuhui Xia, Zelin Zhang, and Lei Wang focused on discovering the rules of association between service demands and remanufacture services in their reported work, *Association rules mining between service demands and remanufacturing services*. The authors propose an improved ant colony algorithm to mine the association rules based on preprocessed remanufacturing service records. The particle swarm algorithm avoids the blindness of the ant colony, effectively enhances the searchability of the algorithm, and makes association rule mining faster and more accurate. In addition, to improve the effectiveness of extracting association rules, a combined heuristic rule mining method is developed. The mining framework used in this paper can be effectively adopted by other smart systems.

Entitled *Assurance monitoring of learning enabled cyber-physical systems using inductive conformal prediction based on distance learning*, the paper of Dimitrios Boursinos and Xenofon D. Koutsoukos addresses an important issue related to the development of smart systems. To realize smartness, various machine learning mechanisms and components are used extensively in these data-driven and software-integrated systems. However, the mentioned AI enablers may introduce hazards and reduce the trustworthiness of these systems. The authors propose a novel approach for real-time assurance monitoring of learning-enabled cyber-physical systems based on the conformal prediction framework. The underpinning concepts of the proposal include distance learning, leveraging conformal prediction, ensuring a bounded error rate, and limiting the number of inputs for which an accurate prediction cannot be made. The computational resources for assurance monitoring are inductive conformal prediction, distance learning deep neural networks, and nonconformity functions calibration. On the one hand, consideration of these influential factors in the design process increases the level of confidence in the system operation. On the other hand, it also gives an example how nondesired effects of applying AI enablers in smart systems can be regulated in the design process. The usefulness and computational efficiency of inductive conformal prediction has been empirically proven. With regard to the reasoning model presented in the first paper, the prediction framework is a practical manifestation of one of the AI-connectors identified between paradigmatic system features and smart system design.

At this point, we would like to gratefully acknowledge the valuable contribution and conceptive cooperation of the authors. The latter helped us a lot to overcome the difficulties caused by the long-lasting pandemic. We are also grateful for the reviewers' insightful and constructive review comments, who helped the authors significantly improve the contents of their submitted manuscripts. In addition, we must thank the editor-in-chief and the technical editor for the opportunity to compile this thematic collection and their professional guidance, advice, encouragement, and unceasing support. We are pleased to dispatch this thematic collection to the readership of AI-EDAM in the hope that it not only provides useful information to many researchers and developers working in various fields of smart designing of smart systems but also contributes to the ongoing, widely based professional debate and stimulates the proliferation of the related methodologies and technologies in the industry.

**Imre Horváth** is an emeritus professor of the Delft University of Technology, the Netherlands. In the last years, his research group focused on research, development, and education of smart cyber-physical system design, with special attention to cognitive engineering. He was the promotor of more than 20 Ph.D. students, and coauthor of more than 440 publications, five of them recognized by best paper awards. He received honorary doctor titles from two universities and various lifetime achievement awards. He is a fellow of ASME. He is the initiator of the International Tools and Methods of Competitive Engineering Symposia. His research interest includes selected topics of smart product, system and service design, systematic design research methodologies, system knowledge science, and development of self-adaptive systems.

**Yong Zeng** is a professor in Information Systems Engineering at Concordia University. He is the President of the Society for Design and Process Science. He was NSERC Chair in aerospace design engineering (2015–2019) and Canada Research Chair in design science (2004–2014). Zeng researches into creative design by developing and employing mathematical and neurocognitive approaches. He has proposed Environment-Based Design (EBD) addressing the recursive nature of design and the role of mental stress in designer creativity. He applies the EBD to aerospace industry, medical device design, human resource management, municipality, teaching and learning design, and preventive medicine.

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