Guest Editorial
Special Issue on Software Engineering Research and Practices for the Internet of Things

SOFTWARE engineering is vital for IoT systems to design systems that are secure, interoperable, modifiable, and scalable. However, industry and academia are still working on many crucial questions related to software engineering for IoT systems, for example, regarding the best practices for developing IoT systems, how to select the hardware, communication, and software architectures of IoT systems, which communications protocols are the most suitable for a system, and how to guarantee security and privacy when dealing with consumer products often composing IoT systems.

This special issue aims at creating awareness in the research and development communities, providing a forum for researchers to share observations, concepts, approaches, frameworks, and practices that promote the role of software engineering and software-engineering solutions in IoT multidisciplinary development environments.

After a warm welcome to our workshop at ICSE 2019 from the software engineering community in Montreal, Canada, on the same topic, we felt the need to prepare a special issue where the best works from our workshop could be presented in more depth. But to our surprise, we received an overwhelming response to our call for this special issue, which surpassed our expectations. We received in total 51 submissions from around the world. During the review process, each article was assigned to and reviewed by at least three experts in the field, with a rigorous multiround review process. Thanks to the great support from the former Editor-in-Chief, Prof. Xuemin (Sherman) Shen, and the current Editor-in-Chief, Prof. Honggang Wang, and the dedicated work of numerous reviewers, we were able to accept ten excellent articles for this issue, and kept others excellent works due to time constraints, for future publication. The articles selected for this special issue cover various topics in software engineering applied to IoT systems. In the following, we will introduce these articles and highlight their main contributions.

In the article "Landscape of architecture and design patterns for IoT systems," Washizaki *et al.* performed a systematic literature review on 32 selected articles from 2014 to 2018, where 143 IoT architecture and design patterns were identified. From these pattern instances, they found that 57% are not specific IoT patterns; the remaining instances focus more on quality attributes like compatibility, security, and maintainability. Their work serves as a reference for practitioners interested in adopting IoT patterns, and for researchers to improve shortcomings in future publications.

In the article "Vulnerability studies and security postures of IoT devices: A smart home case study," Davis *et al.* performed an empirical study on vulnerabilities on well- and lesser-known smart home devices. They found that there is a bias in the literature on vulnerability studies to target mostly devices manufactured by recognized brands (e.g., Google, Amazon, Philips, etc.), where the security postures of these companies are strict. On the other hand, less-known vendors (e.g., Leeo and Feit Electric) with relaxed security postures are not considered in the literature. The findings derived by this work, encourage vulnerability repositories and the research community in general, to include less-known vendor devices to support customers that cannot afford top brands.

In the article "Twenty-one key factors to choose an IoT platform: Theoretical framework and its applications," Ullah *et al.* proposed a framework to assess IoT platforms. The authors derived 21 key factors from the literature and verified them by the Delphi method. These factors, to be considered when evaluating an IoT platform, were compared with current features provided by the top-five IoT platform providers. The IoT platform providers were selected based on their market share and a simple use case is presented. The main contribution of this work is to support companies that are interested to prioritize specific quality attributes like pricing and interoperability when choosing an IoT platform.

In the article "Modeling and analysing an Industry 4.0 communication protocol," Aziz defined a formal model of Hermes, an Industry 4.0 machine-2-machine communication protocol and shown that, despite the robustness of the protocol, many testing scenarios have been ignored in its standard. In particular, scenarios that include simultaneous machine errors. Thus, this article paves the way for a better informed testing strategy in Industry 4.0 systems that implement the Hermes protocol.

In the article "Cities-Board: A framework to automate the development of smart cities dashboards," Rojas *et al.* introduced Cities-Board, a framework to automate the development of smart cities dashboards that transforms dashboards models to functional code artifacts by using model-to-model and model-to-text transformations. They evaluated the proposed framework by measuring the generation time and quality of the generated code under different model configurations. Results show that the generation time is in the scale of seconds (regardless of the amount of generated code) and the generated artifacts are easy to test, maintain, and extend. Cities-Board

Digital Object Identifier 10.1109/JIOT.2020.3026565

is based on model-driven engineering and provides a graphic domain-specific language that allows the creation of smart cities dashboards models.

In the article "Vehicle software engineering (VSE): Research and practice," Moukahal *et al.* studied existing software engineering processes and analyzed their strengths and limitation in the context of connected autonomous vehicles (CAVs). They identified the unique challenges to the VSE field involving software integration, compatibility and code reusability, safety and reliability assurance, and software security and data privacy. Furthermore, they investigated the effectiveness of current practical software solutions, standards, tools, and languages to address the identified challenges. Their work provides guidelines for researchers and practitioners to understand the current practices, trends, and evolution in this research area.

In the article "IoT ecosystems design: A multimethod, multicriteria assessment methodology," Silva and Jardim-Goncalves proposed their model-driven-approach-based methodology to assist decision makers in selecting a more proper device system for a specific task. Their proposed methodology provides a mechanism of multicriteria assessment that takes into consideration the stakeholders' criteria constraints while applying different decision methods. Their work helps the decision makers to perform a better reasoning and more aware analysis of a very diverse criteria, which can be sometimes in conflict, e.g., energy consumption versus computational speed.

In the article "A noble double-dictionary-based ECG compression technique for IoTH," Qian *et al.* proposed a novel lossy electrocardiogram (ECG) compression technique to support IoT devices, specifically wearables, that are typically constrained in battery, memory, and computational power. Compared with the baseline, TASOM model time adaptive self-organizing map, the new compression technique, which makes use of two dictionaries, allows to transfer information at a higher rate. Furthermore, it improves the representation accuracy when a new ECG pattern is read by quarantining the new pattern, without distorting the current dictionary.

In the article "Scalable data storage design for nonstationary IoT environment with adaptive security and reliability," Tchernykh *et al.* proposed an adaptive distributed storage scheme called WA-MRC-RRNS to combat existing risks when deploying IoT solutions on nonstationary environments. They theoretically validated their application by estimating the probability of information loss, data redundancy, and speed of encoding/decoding against well-known weighted secrete sharing and threshold schemes. They estimated that their scheme achieves higher speed, about 13.73 times faster, and 777 times reduction of data loss compared to the MCR-RRNS threshold scheme. However, these gains affected the performance of (de)coding operations. They also highlighted the need of collecting historical information to tune the parameters on nonstationary environment system configurations for future research.

In the article "Continuous delivery of customized SaaS edge applications in highly distributed IoT systems," López-Viana *et al.* proposed an architectural model of highly distributed IoT systems, to support IoT solutions that rely on edge devices. Edge devices can absorb most of the computational activities and make real-time decisions, in areas with poor connectivity and limited energy sources, where quick application response is a paramount. By adopting continuous integration and delivery practices, the authors demonstrated, in a use case of an agriculture prototype, that release engineers are able to customize edge applications on the fly and to serve nontechnical users in remote areas, in a similar way that software-as-a-service providers serve cloud users.

We would like to express our sincere thanks to all authors who submitted their work, and to reviewers for their valuable comments and suggestions that enhanced the quality of the articles presented in this special issue. Special thanks to Prof. X. Shen and Prof. H. Wang for their great support throughout the whole review and publication process and the IEEE editorial staff. We expect that this special issue will serve as a useful reference for researchers, practitioners, and scholars on software engineering and Internet of Things technologies.

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