Bringing Intelligence to Sociotechnical IoT Systems: Modeling Opportunities and Challenges

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Abstract. IoT Systems involve numerous interconnected things that sense or enact on the physical world to support customized software services for human beings. From a software and systems engineering point of view, such systems are essentially complex sociotechnical systems that lead to the development of dynamically adaptable, cyber-physical, systems. The adaptability with regards to the physical environment comes from a feedback (control) loop (*e.g.,* MAPE-K loop) assimilating data from the sensors, building a model of the surrounding environment, planning or possibly predicting new scenarios, and soliciting the actuators accordingly, in the form of a sequence of actions.

As with any sociotechnical systems, the planning process is usually semi-automatic, highly interacting with final users to provide the best experience. Various software services have been developed in the past decade, leveraging important frameworks developed by the IoT community (*e.g.,* protocols and gateways), and leading to a wide range of smart systems in energy, production systems, robotics, transportation, healthcare, agriculture among others. The smartness of the system comes from the ability to bring intelligence into the feedback loop. This intelligence primarily leverages the assimilation and curation of the acquired data. However, as a sociotechnical system, it is of outermost importance of also considering broader physical, economic, social and environmental concerns in which the systems and final users involved. Since such information is difficult to get from sensors or to hard-code into the software itself, additional information must be combined with the available data to provide a holistic and systemic view of the system and its environment, support for making informed decisions. This need is currently supported by the concept of digital twins.

When comes the time of designing such a feedback loop, modeling appears to be key. Modeling is key to capture any sort of knowledge in the form of descriptive models built from acquired observations or data, and modeling is also key to drive the development and evolution of complex

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systems in the form of prescriptive models reducing the accidental engineering complexity. The gap between the descriptive models and the prescriptive models can be made manually, or automatically through predictive models.
In this talk, I review the various types of models required for intelligently designing software services on top of IoT systems, and I discuss the different roles such models are playing in the overall lifecycle. I present the opportunities for the modeling community, as well as the open challenges to be tackled to achieve such a vision. In particular, I explore the required common modeling foundations for seamlessly combining the different types of models, and the development of complex digital twins to support informed decision making in the feedback loop of smart sociotechnical IoT systems.

Keywords: IoT, Sociotechnical system, Cyber-physical system, Model Composition

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