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TOWARDS A GENERIC ARCHITECTURE FOR SYMBIOTIC SIMULATION SYSTEM-BASED DIGITAL TWIN

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ABSTRACT

Digital twin (DT)—one of the most prominent technologies in the Industry 4.0 era—has the ability to integrate the physical and virtual worlds, such that the data exchanged between them could be used to support decision-making and improve operations. DT could benefit from advancement in symbiotic simulation system (SSS), which has been used for so many years, prior to the advent of Industry 4.0, to interact with physical systems and support decision-making using the data from their interaction. Therefore, this paper will propose an SSS-based generic architecture for DT that satisfies DT requirements.

1 INTRODUCTION

As basic requirements, a digital twin must, be a virtual version of a physical system that retains connectivity and exchange data with, be dynamic and synchronized with, and have the ability to detect anomalies in, the physical system (Moyne et al. 2020). Symbiotic simulation system (SSS) satisfies these requirements, as it interacts with physical systems, by using near real-time or real-time data generated by the physical system and shared through a communication channel (Aydt et al. 2008). These authors categorize SSS into closed-loop (namely: symbiotic simulation control system (SSCS) and symbiotic simulation decision support system (SSDSS)) and open-loop (namely: symbiotic simulation forecasting system (SSFS), symbiotic simulation model validation system (SSMVS), and symbiotic simulation anomaly detection system (SSADS)). These SSS types are introduced to the digital twin layer of a generic architecture for a DT.

2 RESEARCH GAP AND METHODOLOGY

There is an urgent need to develop a systematic DT architecture, because none of the existing architectures is generally accepted (Liu et al. 2020). Although, the concept, purpose, applications and challenges of digital twin and symbiotic simulation systems are the same (Shao et al. 2019), there is currently no DT architecture that employs SSS. Therefore, using a theoretical research approach, the subclasses of SSS are applied to the DT layer to develop an SSS-based DT architecture that meets the requirements for a DT.

3 ARCHITECTURE FOR SSS-BASED DIGITAL TWIN

The proposed architecture (Fig 1) is a four-layered architecture, consisting of the physical, communication, digital twin and application layers. The DT layer consists of symbiotic simulation module, data acquisition module, data analytics module, optimization module, machine learning component, scenario manager and actuator. The symbiotic simulation module includes the subclasses of SSS (SSCS, SSDSS, SSADSS, SSFS, and SSMVS). SSCS is used to control the physical system directly using an actuator, while SSDSS is used to control the physical system through an external actuator (e.g. a decisionmaker). The SSADS is concerned with identifying anomalies in the simulation or physical system, by using a reference model to compare the simulated behavior of the physical system with its actual behavior. SSFS uses different what-if analyses to forecast the behavior of a physical system, and the result of these what-it analyses can be used for further analysis or visualization process by an external process. As the name implies, SSMVS is used to validate models and aims at identifying a reference model, which is the most accurate representation of the current behavior of the physical system. The architecture employs message queue telemetry transport (MQTT)—a lightweight/flexible, many-to-many communication protocol that supports a bi-direction communication between multiple clients, through a common broker. This framework aligns with DT requirements in Moyne et al. (2020).

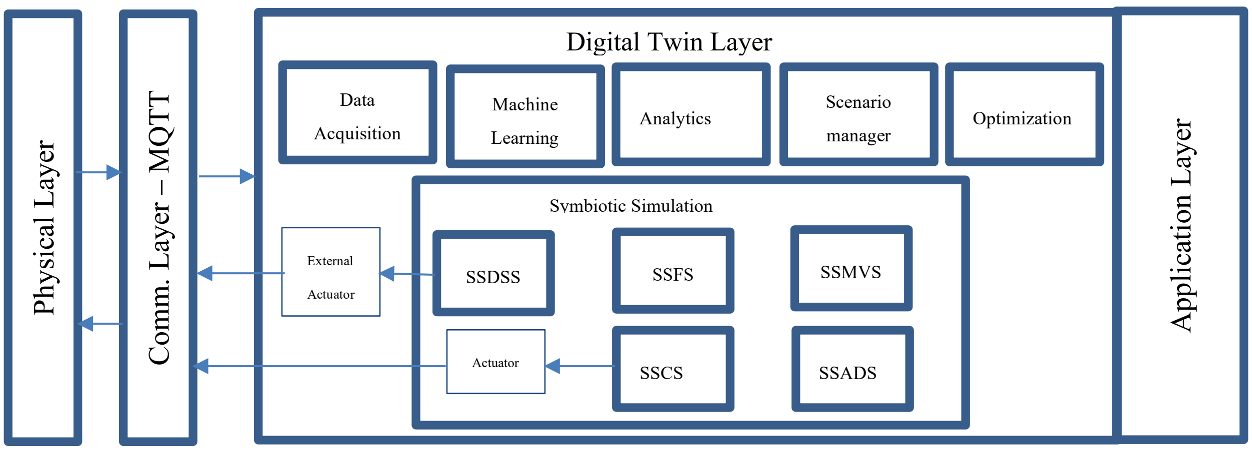

Fig 1: A generic architecture for symbiotic simulation system-based digital twin.

4 CONCLUSION

There is overwhelming evidence in literature that Digital twin (DT) is an evolution of symbiotic simulation system (SSS). This includes Onggo et al. (2020), who feature DT applications in their discussion on the applications of SSS. In this paper, the correlation between DT and SSS is demonstrated, and the classifications of SSS are discussed and applied to the simulation module of the digital twin layer of a DT architecture. To the best of our knowledge, this is the first application of SSS to DT architecture. We conclude that the research into DT will benefit immensely from the advancement in SSS. Future work might be concentrated on applying this architecture to various use cases, as well as describing its features and advantages in details. Implementing this architecture on digital twin design might be part of future research.

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