Proceedings of the 2024 Winter Simulation Conference
H. Lam, E. Azar, D. Batur, S. Gao, W. Xie, S. R. Hunter, and M. D. Rossetti, eds.

TOWARDS THE INTEGRATION OF A PRODUCTION PLANT DIGITAL TWIN EXPLOITING MES DATA AND PROCESS MINING

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ABSTRACT

This research focuses on analyzing the functional requirements for implementing a Digital Twin (DT) in a manufacturing environment, with the aim of improving decision-making for scheduling activities through simulation. The project is being developed in collaboration with a company in northern Italy; aiming to create a Discrete Event Simulation (DES) model for predictive process monitoring and to propose rescheduling options in response to potential delays. The primary challenges anticipated include integrating data from diverse sources such as ERP and MES systems, ensuring data quality and adapting the existing system to support the DT framework. It will be crucial to integrate the DES model with other tools and techniques, such as Process Mining, to achieve dataflows integration and synchronization.

1 CONTEXT AND MOTIVATION

In the context of Industry 4.0 and 5.0, the emergence of various opportunities for advancing innovative technological solutions has given rise to the challenge of effectively integrating them.

Building on the principles of simulation, Boschert and Rosen (2016) present Digital Twin technology as the “next wave of simulation". The concept of Digital Twin, originally introduced by Grieves (2005) as a "mirrored space model" involves a physical space and a virtual space, interconnected by bidirectional flows of data and information. Although there is no consensus on its definition due to its wide range of applications, a Digital Twin can be defined as “a virtual representation of a production system capable of running different simulation disciplines characterized by the synchronization between the virtual and the real system” (Negri et al., 2017).

The Digital Twin is a highly adaptable and precise tool that can be used in various application fields, including biomedical, civil sector, urban planning, and mining. The traditional fields where the DT is commonly used are engineering, computer science, aerospace. This PhD project focuses on implementing the Digital Twin in an industrial setting to enhance decision-making in the manufacturing sector. This DT must accurately depict the manufacturing industry of a company located in northern Italy, and effectively and productively integrate data from ERP (enterprise resource planning) and MES (manufacturing execution system). To enable proper interconnection between the virtual and real counterparts of the Digital Twin, the use of data analysis techniques, specifically Process Mining (PM), is deemed necessary. For insights into the synergistic link between DT and big data, refer to Tao et al. (2018) and Qui and Tao (2018).

The research goal of the project is to analyze the functional requirements for the implementing a DT in a manufacturing industry, specifically in a company that shares similarities with Small and Medium Enterprises. The objective is to evaluate the impact of this implementation on the system, while developing a framework for integrating simulation systems, PM, and business information systems to enhance internal decision-making processes.

2 PROJECT APPROACH AND DISCUSSION

The implementation of the corporate digital twin project can be analyzed based on several dimensions and challenges. These include: the technical selection of the digital counterpart for the digital twin; the company's objectives; the purposes of the DES model; the requirement for integration with information systems; the necessity of adapting the existing real system to enable the implementation.

Following a software/tool selection process, a Discrete Event Simulation (DES) model was chosen as the virtual counterpart of the Digital Twin. The DES model will be implemented in Python using the Simpy library. By the specific characteristics of the environment under analysis determine the selection of a discrete-event simulator. In this case, the company operates a large number of machines and processes batched orders, making a discrete-event simulation model the most suitable approach to describe the system accurately. It is important to underly that the data fed into the DES model will be prepared and preprocessed with PM techniques. The decision to opt for an open-source tool is motivated by the necessity to seamlessly integrate other existing functions within the company and to avoid the substantial initial costs associated with the project, reflecting a cautious approach during these early stages.

The company has two main goals: operational goals and organizational goals. The operational goals focus on enhancing on-time demand satisfaction. This defines the two main goals of the DES model itself, as will be further explained later. The aim of the organizational goals is to enhance the efficiency and accuracy of processing times, cycle times, and makespan updates for different codes. The Digital Twin will autonomously acquire some of this information and auto-adapt, eliminating the need for explicit efforts from the company.

As anticipated, the DES model serves two different purposes that align with business operational goals. The model will both need to monitor production progresses from a predictive process monitoring perspective, alerting appropriately when a batch is expected to be completed late, and it will need to propose rescheduling options should it be decided to take action to avoid such a reported delay. This second function requires the optimization through simulation of what-if scenarios, and it is the core functionality supporting and improving decision-making.

Integration problems arise from the challenge of managing data from various and unevenly structured sources, coupled with the absence of explicit information about cycle times and processing times. Given that the data structure and the simulation scenarios obtained through the DES model will rely on the historical data obtained from the MES, and given the difficulties in handling such a large volume of data, it is required that data analysis techniques, such as PM, to appropriately prepare and preprocess the data that will be fed into the DES model.

The adaptation of the real system is necessary due to challenges that cannot be resolved through PM alone. Relying only on historical data as the reference for the scenario analysis obtained through the DES model is inherently fragile, and certain types of data corruption or lack thereof can make the entire process unreliable. Therefore, it is crucial to establish an unambiguous standard for the quality of the required data.

The ongoing work, currently in the implementation phase of the DES model, aims to thoroughly assess the complete implementation of a Digital Twin. This evaluation includes analyzing the benefits, challenges, difficulties, positive and negative impacts on the system under study.

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