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REAL-TIME GENERATION AND EXPLOITATION OF DISCRETE EVENT SIMULATION MODELS AS DECISION-SUPPORT TOOLS FOR MANUFACTURING

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ABSTRACT

Complex manufacturing systems require digital decision-support tools for optimal production planning and control. Discrete event simulation models can guarantee the ability to take prompt decisions at any time, provided the availability of an up-to-date model. Hence, techniques for a prompt model generation or adaptation to the physical system have to be developed. Literature is rich of approaches to generate digital models from available datasets. Yet, such techniques are mostly suited for managerial processes and cannot support properly manufacturing applications. This research regards the automated model generation for production systems. The research is beneficial for the development of real-time decision-support system in manufacturing environments.

1 INTRODUCTION

In manufacturing environments, the ability to take appropriate decisions exploiting digital models is strongly based on the assumption that models are properly aligned with the real system. However, manufacturing systems change regularly due to both external drivers and internal decisions (e.g., moving robots or machining stations). In this context, the time to develop a new model may hinder its exploitation along the production systems life cycle. Industry 4.0 contributed to the rise of new technologies for data acquisition, storing and communication, allowing for the knowledge of the shop floor status at anytime (Tao, Qi, Liu, and Kusiak 2018). The availability of real-time data suggests that if a model could be generated from the available data in the manufacturing system, the development phase may be significantly shortened.

Recent approaches introduced the exploitation of process mining techniques (van der Aalst 2018), which enable to retrieve the system topology from the manufacturing system data (Popovics and Monostori 2013). However, practical implementations of automated model generation remain scarce. One of the reasons is the difficulty in adapting the level of detail of the model (Nikula, Paavola, Ruusunen, and Keski-Rahkonen 2020). Indeed, such step is essential for removing complexities that may hinder both the understandability and the re-usability of digital models. This work develops techniques to build and test discrete event simulation models of manufacturing systems, aimed at their exploitation online as decision-support tools.

2 RESEARCH OUTLINE

This research focuses on the development and adoption of automated model generation techniques for obtaining simulation-based digital models starting from the data logs of manufacturing systems, together with methods to tune the models toward a desired level of detail. Figure 1 shows an overview of the research. The methodology starts with the extraction of valuable knowledge from production data logs. For instance, precedences among activities can be retrieved from the combined information of sensors readings and part

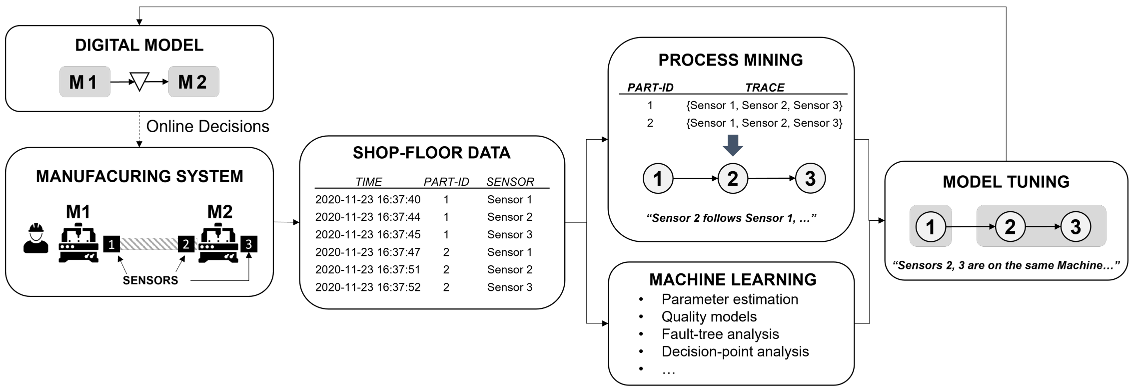

Figure 1: Graphical outline of the research.

identifiers (Lugaresi and Matta 2021). In addition, manufacturing system properties and parameters such as buffer sizes are estimated from data through inference algorithms. The system properties are also used in a model tuning approach, which generates an adjusted model starting from the available knowledge and the user requirements in terms of complexity (e.g., number of stations).

3 RESEARCH IMPACT AND NEXT DEVELOPMENTS

Results on a real dataset from 5000 events demonstrated the possibility to generate an adjusted digital model within one minute (Lugaresi and Matta 2021). The proposed automated generation and tuning method can positively contribute to real-time simulation. Indeed, the online application of the proposed methodology allows for adapting simulation models to the real system counterpart, potentially at any time a modification occurs. This way, decisions taken online are guaranteed to be referring to the current state of the physical system. As a result, manufacturing enterprises can reach a higher production flexibility, together with higher responsiveness to technology changes and market demand fluctuations.

Next developments of this research shall investigate the adjustments of the tuning approach to different types of manufacturing systems. For instance, job shops are characterized by several independent part flows, which may result in a more complex identification of the system structure. At the same time, the estimation of certain parameters might be more straightforward (e.g, the buffer sizes in a job shop may be considered as infinite). In general, a situation of partial knowledge is much more realistic. For instance, the buffer capacities might be available in advance, while the processing times of certain stations might be unknown. Future works shall also develop specific tuning rules for realistic applications with a large number of activities. Last but not least, research should focus on how to combine the results of different mining algorithms (e.g., material-based and information-based) in a unique and consistent framework.

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