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SUPPORTING AUTOMATED WAREHOUSES WITH DATA-DRIVEN MODELLING

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ABSTRACT

With the recent increased pressure on supply chains, Automated Storage and Retrieval Systems (AS/RS) play an key role in improving the efficiency of logistics processes. Data-driven simulation modelling coupled with Machine Learning (ML) algorithms might represents an effective approach to anticipate problems that may occur in the warehousing processes. Thus, this PhD project aims to develop an advanced data-driven simulation model for supporting the decision-making process related to AS/RS operations. To this end, the objectives are to evaluate the state-of-art of AS/RS simulation, develop and validate a data-driven simulation model, and integrate it with a ML algorithm to reduce the cycle time. Finally, potential application of this approach will be tested in different operational settings.

1 INTRODUCTION AND RESEARCH BACKGROUND

The last decades have seen rapid advances in the field of AS/RS. They have been gathering momentum thanks to their advantages with respect to more traditional warehousing systems, such as the efficient utilization of the warehouse space, reduction of damages and loss of goods, improved inventory control and decreased number of warehouse operators (Fandi et al., 2022). During the years, AS/RS have been mostly studied using simulation and modelling approaches to improve and optimise the system performances at different levels depending on design decisions. The most exploited methods for a better estimation of the warehouse processes are analytical modelling (Lehmann & Hußmann, 2021), and discrete events simulation (DES) (Marolt et al., 2022). Moreover, from the literature, it emerges that Shuttle-Based S/RS are the most widespread system configuration analysed through simulation techniques (Ekren, 2020), followed by the traditional AS/RS (Xu et al., 2016), and Autonomous Vehicles S/RS (Liu et al., 2018).

With the recent growing dominance of e-commerce and the increased pressure on supply chains, AS/RS are required to be more and more flexible to handle the day-by-day operations. Nevertheless, AS/RS configurations are generally taken as fixed in the models developed by researchers. Data-driven simulation modelling is a technique in which dynamic elements are introduced in the model based on data derived from the physical system. Moreover, the recent increase in data availability and the emergence of new digital technologies enable managers to cope with uncertainties using intelligent decision-making approaches (Cavalcante et al., 2019). To manage such an increased complexity, scholars have been using ML algorithms to cope with dynamic workloads in automated warehouses, especially with regards to Automated Guided Vehicles (Deng et al., 2020; Ha et al., 2021).

Therefore, data-driven modelling with ML result in a higher flexibility of the model in comparison to a static one. However, the literature on this approach applied to the AS/RS arena is scant thus far.

2 RESEARCH OBJECTIVES AND APPROACH

The goal of this work is to propose an advanced data-driven simulation model (DDSM) for supporting the decision-making process related to AS/RSs operations. This can be decomposed in the following research objectives:

1) Evaluate the state-of-art of simulation modelling in the context of AS/RS;
2) Develop a DDSM for AS/RS;
3) Validate the model on a case study;
4) Develop a ML algorithm to reduce the AS/RS cycle time;
5) Test the model in different operational settings.

This PhD project is still at the beginning and it should be completed by the end of October 2024. To achieve the first objective, a Systematic Literature Review has been submitted to an international journal. Then a DDSM based on DES and replicating the functioning of an AS/RS installed in the laboratories of Politecnico di Torino was built through the AnyLogic platform. At the moment, the DDSM replicates the storage process of the AS/RS and the movement of unit loads. The retrieval process of the AS/RS, the picking operations and the inventory are under development.

Regarding the validation, only the storage process was taken into account and it was validated via a set of experiments carried out following the Design Of Experiment (DOE) approach. The retrieval process will be validated once the DDSM is completed.

The more suitable ML algorithm will be adopted from pertinent logistics and warehousing literature, taking into account the objective of reducing the AS/RS cycle time. Then, operational data will be generated by running the DDSM over different operational settings, and they will be used as input for the ML algorithm. Finally, the DDSM integrated with the ML will be used to support AS/RS operations.

3 IMPLICATIONS

This PhD project will develop an advanced data-driven simulation-based decision-making support tool to better manage the operations of AS/RS. Potential application of this approach might be consequently proposed to specific logistics contexts in different fields highlight both advantages and disadvantages of the application of such technology from an operational and economical perspective.

Another important implication of this work is the Digital Twin (DT), defined as the simulation-based virtual counterpart of a physical system, exploiting a real-time synchronization of the sensed data coming from the field in order to optimize the actions undertaken by the physical system. Even increasingly considered promising and effective, the DT is scarcely used in the evaluation of automated warehouses.

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