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LOGISTICS 4.0 – A CHALLENGE FOR SIMULATTION

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ABSTRACT

Technological innovation and requirements of modern production are leading to a significant transformation of logistics. Cyber-physical systems are introduced as an integrating concept for improving information flow from execution to decision systems and vice versa. Accompanied by decision and information systems with an increasing degree of autonomy, new challenges arise in modelling and implementing autonomous logistics, i.e., Logistics 4.0. Thus, sophisticated simulation approaches are required, capable of representing both: material flow and automation systems as well as autonomous software systems and human actors. This paper aims at discussing two integrating approaches to simulate decision makers and logistic processes in the context of Logistics 4.0.

1 INTRODUCTION

In recent years, the field of logistics has changed significantly due to the high amount of technological innovations. In production engineering, cyber-physical systems (CPS) have been introduced as integrating concept for improving the bidirectional information flow between execution and decision systems. These systems have to be considered in logistics, too. Especially technological innovation supporting physical logistic processes leads to systems with increased computational and communication capabilities, as all resources and relevant components of a product are able to communicate with each other for exchanging necessary information. In analogy to the concept Industry 4.0 known from production engineering, Logistics 4.0 describes the transformation from hardware-oriented logistics to software-oriented logistics, i.e., smart service world.

Within the context of Logistics 4.0, logistic systems consist of autonomous sub-systems, where the behavior of individual actors depends on other actors or sub-systems in the "neighborhood". The autonomous systems interact with each other for pursuing their individual goals and the goals of the respective stakeholders. Thus, they are implementing local optimization, which leads to emergent behavior. As of this, it is uncertain how to guarantee, that individual behavior and emergent effects do not lead to global chaos, where no reliable prognosis on the system's outcome is feasible. Consequently, new challenges in modelling, engineering, and implementing autonomous logistics arise and require sophisticated simulation approaches capable of representing both: material flow and automation systems as well as autonomous software systems and human actors. Hence, the objective of this paper is to discuss integrating approaches to simulate decision makers and material flows of logistic processes in context of Logistics 4.0.

2 SIMULATING LOGISTIC PROCESSES

During the past 20 years, material flow simulation has been established as standard means for modeling and optimization of material flow systems like logistics. For this purpose, different software tools have been developed and are applied in business and management. These tools are based on discrete event simulation, thus, the system's states are transformed into discrete time steps. Accordingly, logistic systems can be analyzed regarding the occurrence of and reaction to events, such as the arrival or completion

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of orders, delays, technical failures of machines or rearrangement of production lines. In contrast to continuous simulation, decisions in discrete event simulation are following strategic deliberation processes, as addressed in game theory.

Tools for simulating logistic processes provide relevant functionalities for performing simulation experiments, e.g., a modeling environment, a graphical representation of the simulation model, support for visualization of simulation dynamics, data input and output interfaces, and support for statistical analysis of simulation results. Furthermore, these tools contain a library of predefined entities for efficient modeling of real world logistic systems, e.g., specific machine tools or transportation technology.

However, flexibility in these systems is limited and individual decision behavior can only be implemented using a proprietary programming language. Furthermore, the common representation of products as tokens is no longer sufficient, as the product itself needs to be capable of actively and individually communicating with other entities involved in the production process, for enabling an optimal and customized manufacturing of the product. Therefore, multiagent-based simulation (MABS) is used in research for analyzing Logistics 4.0 scenarios. Doing so, the production flow can be improved, as machine allocations can be negotiated dynamically by the products themselves. Using different negotiation mechanisms, e.g., auctions, an optimal allocation of available resources and the compensation of machine failure is facilitated. Consequently, the question arises, whether material flow simulation should be extended using MABS or MABS should be extended by concepts of process simulation for simulating Logistics 4.0 scenarios. Considering this, two different approaches seem to be suitable: (1) extending process simulation with concepts for MABS or (2) combining a process simulation tool with a MABS tool. Hence, we conducted two studies for evaluating the feasibility of these approaches for simulating Logistics 4.0.

The first approach aims at modifying and extending existing components of material flow simulation platforms. For enabling negotiation and coordination, machine tools and products have to be enhanced by communicative behavior and intelligent decision mechanisms. Due to practical reasons, the physical layer of the model needs to be accompanied by a virtual layer, containing virtual representatives of each modeled entity. Even though this is a workaround in context of the simulation tool, it is close to real-world Logistics 4.0 applications, where physical entities, like machine tools, are virtually represented by a CPS as an autonomous decision-maker, too.

In contrast to this, the second approach aims at enabling more sophisticated decision-making. Hence, dedicated frameworks for developing multi-agent systems (MAS) need to be used for implementing the individual representatives of the production entities, as they provide a set of methods for developing and controlling autonomous agents. In consequence, two separate systems need to be developed and the exchange of messages between the systems needs to be implemented using standard for data exchange, e.g., XML, TCP/IP or databases. Doing so, products and machines located in the material flow model can pass their demands to their individual representative in the MAS system, which can then communicate and negotiate with the other entities' representatives. When a result is obtained, the information is passed back to the material flow model and the action is executed by the corresponding machine or product.

3 RESULTS AND CONCLUSIONS

Both studies outline the feasibility of the proposed approaches. However, in both studies significant expenses are necessary for the consideration of alternative physical transportation paths to allow for flexible assignment. The findings of the studies can be summarized as follows: When extending process simulation, any resource or human actor with autonomous abilities has to be modeled in a separate virtualization level. Furthermore, some concepts provided by the tool will be misused for another purpose, such that there is divergence of syntactical and semantic interpretation of the model. In contrast, when combining process simulation and MABS, additional expertise is required for modeling agent behavior and the synchronization of both systems is a non-trivial aspect, yet, a high potential for integrating sophisticated decision-making in process simulation exists. Finally, the value of this paper can be summarized as follows: Integrating autonomous decision makers into conventional material flow simulation, as required for addressing the requirements of Logistics 4.0, results in increasing complexity. The feasibility of combining MABS and process simulation using state-of-the-art software has been shown. Yet, this is only a first step for an integrated simulation in Logistics 4.0.