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Autonomous control in closed dynamic logistic systems

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Abstract

The material flow in dynamically changing logistic systems underlies specific conditions, as destinations and stop-overs only exist temporarily. The order-dependent circulation of rental articles constitutes such a case, where the articles are on the move between the lender and one or more customers. The related planning and control processes are highly complex and challenging as they comprise the scheduling of orders, the compilation of transports and the determination of suitable routes. This paper introduces an autonomously controlled approach for the distribution of rental articles, including the autonomous decision-making and the representation of the involved objects as autonomous entities. A use case from the field of event logistics illustrates the proceeding for the integration of the approach in real world processes.

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1. Introduction

The business field of event logistics constitutes a dynamic and complex environment regarding the logistic planning and the corresponding control processes [1, 2]. Generally, event-related rental articles circulate between the lender and one or more customers, using a steadily changing logistic network [3]. At this, the different venues

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only exist temporarily and can change due to varying orders. Further, occurrences such as damages or thefts of articles and/or transport devices as well as versatile traffic conditions complicate the logistic planning. The result is a frequent replanning of transports and routes that often also affects the general scheduling of orders and the related personnel planning [4, 5].

From a scientific point of view, the order-related distribution of rental articles in closed dynamic systems touches three well-known problems; order-dependent resource allocation (resource distribution/scheduling), transport planning and route planning [6]. Therefore, a manual and centralized accomplishment of the logistic planning is time-consuming and often leads to inefficient and costly processes [1]. Besides the further optimization of established centralised control approaches, the application of alternative approaches, such as the paradigm of autonomous control, seems to be promising in order to deal with the above mentioned challenges.

The Colloborative Research Center 637 “Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations” focused on the development, implementation and evaluation of autonomous control methods in production and logistic networks [7]. This paper introduces a concept that combines methods from the CRC 637 and transfers them into practical application. At this, it deals with a distribution system for the resource allocation in event logistics that includes the compilation of transports and the determination of the best routes within the logistic network. The system applies three methods from the field of autonomous control, namely the Autonomous Logistics Engineering Methodology (ALEM), the Platform for Simulation with Multiple Agents (PlaSMA) and the Distributed Logistics Routing Protocol (DLRP), to compute all required planning decisions within scenario-based simulations of a Multi-Agent System (MAS) [8, 9, 10, 11, 12, 13, 3]. Altogether, the combined application of the three methods can be seen as a Cyber-Physical System (CPS), as the representation of the logistic objects and the transport network forms a digital image of the real world that comes into operation to make decisions that are viable for the physical objects [14].

An example company acts as a use case to demonstrate the specific conditions related to event logistics and to illustrate the starting points of the autonomously controlled distribution system. At this, the structure of the paper will be as follows: directly after the introduction in section 1, the following section 2 introduces the use case and the field of event logistics in general. The third section deals with the autonomous control approach, the implementation and an integration concept regarding the use case, followed by section 4 with first experimental results. Finally, section 5 summarizes the paper and gives a short outlook on future work.

2. Use Case

The example company is a full-service agency from the field of event management [1]. With its 60 employees, spread over the company headquarters and several branches for marketing and customer services as well as an annual turnover of 7 million euros, the company constitutes a small or medium enterprise (SME) [1] At this, the company offers all services related to the execution of public and private events, such as weddings, company anniversaries, product presentations, exhibitions and so on [2]. The service package includes the artistic programme planning, the letting of event-equipment, ranging from chairs and tables over catering devices up to complex stagecraft as well as the related logistics. Further, the company takes over the construction and dismantling of the event equipment at the venues [2].

The logistics operates from the central storage directly at the company headquarters and comprises an internal car pool of three vans (3.5tons), two medium trucks of 7.5 tons and a lorry with 40 tons. Additionally, four cars are available for the transport of small devices and/or personnel [3]. The logistic planning processes of an event take place within the five staged general planning that starts with the order receipt (stage 1) [1]. In the following, a rough planning (stage 2) determines the artistic requirements in cooperation with the customer and derives the preliminary demand of event equipment. The detailed planning in stage three specifies the latter, before the realization begins in stage 4. The event accomplishment follows in stage five and comprises the transport and setup of the event equipment. An event ends with the dismantling and backhaul to the central storage or to a subsequent event. Formally, an event ends with the post-processing and billing [1]. Table 1 enumerates the single phases and the related activities, as they take place within the example company.