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Knowledge-Based Decision Making in a Cyber-Physical Production Scenario

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Abstract

Market requirements such as shortened product life cycles as well as the increasing number of variants up to customized products lead to more complexity in production systems. Digitalization initiatives, such as the vision of "Industrie 4.0", try to cope with this complexity by means of smart products and smart machines that are equipped with their own decision making capabilities for steering flexible ad-hoc production processes. In this paper, we discuss the use of semantic technologies together with cyber-physical systems for integrating decision making into smart production machinery. We report on the experiences with a prototypical realization based on Semantic Web technology on top of a complex cyber-physical production demo system at the Fraunhofer IGCV in Augsburg.

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1. Introduction

Industrial production is facing major challenges with regard to flexibility and productivity. Due to the dynamization of product lifecycles and the continuously increasing number of product variants - ideally the customer wishes to purchase an individually designed product - the complexity of production processes rises. In addition, a high productivity rate is required for companies to remain competitive. In order to deal with these challenges, the need for efficiency, flexibility and responsiveness arises in the area of manufacturing processes [1].

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Moreover modern information and communication technologies (ICT) are more and more used in the industrial production. Digitalization, which is already known from the consumer area, is also making inroads into the factory buildings. With the slogan "Industrie 4.0" digitalization of production is recognized. Products and resources are equipped with sensors, embedded systems and communication interfaces. Large amounts of data are being produced and have to be processed and communicated. So-called cyber-physical systems (CPS) make it possible that machines can communicate with each other but also machines and products can interact and exchange data. These are called cyber-physical production systems (CPPS). On the basis of the data they produce, automated decision making can be incorporated into production processes. The advantage is that this database is more precise and recent compared to conventional production systems [1, 2].

The objective here is the intelligent networked production, which can be defined as the manufacturing of products with the help of digital technologies and with respect to products, processes and resources in line with the production development process. This brings new possibilities of decision making to production planning and control. Absolutely decentralized decisions have proven not to be purposeful. So a knowledge-based approach has been developed, which combines the advantages of centralized and decentralized decision making [1, 2].

However decision making can now be outsourced to individual production resources, so that faster decisions can be made based on the obtained data and can be implemented locally. The complexity of decision making is reduced. The decision will no longer be made centrally but, at a certain level, decentralized [1, 2].

This paper presents an approach of knowledge and information modeling for a CPPS and shows an exemplary implementation of automated knowledge-based decision making with a mobile robot as an intelligent component in a production environment with high variant product range.

2. State of the Art

Essential for the realization of our approach are CPS in manufacturing systems. The following sections show the state of the art concerning CPS and further research fields which are elementary for knowledge-based decision making in cyber-physical production systems.

2.1. CPS in manufacturing

CPS are embedded systems, which are enhanced by the possibility of networking. They are relevant for various applications such as mobility, medicine, production and energy technology. They represent a fusion between the real and the virtual world: They acquire data from their environment through appropriate sensors or user interfaces, additionally they also can process and aggregate the acquired data [2].

However, the feature whereby CPS form a great additional value for the specific application is not the mere digitalization of the data or the system and the integration of software, but also the ability of communication. CPS are able to be constantly connected to local or global networks to communicate with other CPS ("System of Systems"). The aggregated data can then be communicated via the network. For communication with other CPS knowledge about one's condition is a prerequisite. Therefore the ability of self-description of CPS can be considered as another key capability. Thus, the important elements of CPS are the following [3, 4, 5]:

- Intelligence: the elements have the ability to process the information which they receive from their environment, autonomously via appropriate interfaces; thus these elements are able to cooperate and collaborate,
- Communication skills: the ability to establish a connection to other CPS via networks (WiFi, Internet, etc.) and
- Adaptability: ability to adapt to external and internal changes.

The integration of CPS in a manufacturing environment leads to CPPS. CPS are key enablers of networked production. CPPS consist of intelligent, flexible and interconnected elements which make autonomous decisions and intervene in the production process. Especially potentials to realize a flexible production can arise from the implementation of CPPS. A situational production control becomes possible because of the precise knowledge of the production system’s status and the states of the individual products [4].