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Integrated data model and structure for the asset administration shell in Industrie 4.0

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Abstract

The increasing demand for highly customized products in connection with shortened product life cycles requires the manufacturing industry to be eminently flexible, whereas low production costs are crucial to persist in the competition of the global markets. To meet this requirements, cyber-physical systems (CPS) are applied into the production process, aiming for interconnected and self-managing smart factories, which can incorporate external and internal conditions for the autonomous adaptation to gain optimized results. This is achieved through a bi-directional information flow between all important components such as machines, products, control programs and off-site assets. Therefore it is essential to standardize communication interfaces and enhance interoperability between CPS of all variations. This paper presents an approach to combine the specification of the World Wide Web Consortium (W3C) with the guidelines of the Plattform Industrie 4.0 (I4.0), thus obtaining a uniform structure for industrial CPS. Based on the recommended asset administration shell for I4.0-components, the required functionality is identified and allocated to different segments. The five main segments include the functionality for security, representation, communication to external CPS, communication to internal assets and a section for additional applications to enhance the capabilities. By using a standardized protocol for the configuration and representation based on the object memory model of the W3C, a significant interoperability between I4.0-components and conventional Internet-of-Things can be realized. The proposed structure is applied in a use case to simulate the adaptation and remote maintenance of a production robot.

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Keywords: Cyber-Physical Systems; Industrial Internet; Industrie 4.0; Internet of Things; Remote Maintenance

1. Introduction

A significant research subject of the past century was the development of new methods to manage increased lot-sizes in the production process. This subject pervaded through the decades, changing the production structure from former hand-crafted products to fully automated production lines, thus increasing the affordability and expanding the customer circle. The developed methods furthermore had to consider the continuously decreasing product life cycles (PLC), which require an appropriate degree of flexibility to adapt to recent developments and integrate new technologies into the production [1,2]. Thereby flexibility was primarily determined by the time-to-volume, which measures the necessary time and efforts for the alteration of a mass production system to integrate new technologies. In recent years the customer demands have increasingly shifted from mass products to personalized devices. Automotive manufacturers for instance have to offer a huge amount of specifications and optional features which can be chosen and changed by the customer. This leads to a tremendous expansion of the product variety. In combination with the lean-production methods designed to avoid inventory, the result is a significant reduction of lot-sizes. The final stage of this process is a production system which is continuously adapting to every new order, while the value stream is constantly changing. To remain a high productivity, the adaptation itself has to be automated, thus individual orders can be processed seamless within the production system. The

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opposing requirements of highly automatized yet flexible systems can be accommodated with the application of advanced information and communication technologies into the production process. The application is enabled by the remarkable developments on the field of computer science. Overall the hardware components are getting smaller, cheaper and more efficient. Combined with the perpetually expanding Internet availability and improving web technologies, an extensive communication network has been created, thereby supporting the fundamental requirements for huge data collection. The impact is most apparent in the private sector and customer goods. Advanced computer technologies are already used on the shop floor, mostly integrated into the production stations as embedded systems, which can control machines and processes on a restricted level [3]. Additionally the technologies are indispensable at the office and administration level. The management of the complex product creation process extensively uses advanced information and communication technologies, mainly for Product Data Management and Enterprise-Resource-Planning. Nonetheless the processes are controlled in the hierarchical structure of the automation pyramid. Consequently the next step is to improve the production machines and the supporting components into autonomous systems, which comprise external and internal conditions for the adaption process. The adaptation process may require complex software programs. Therefore all relevant components of the production system have to be transformed into cyber-physical systems (CPS). A CPS can identify itself, set up a connection with surrounding network systems, interact with other CPS and have additional functionality. In the context of the production process each batch, production machine and separate asset can be CPS. For instance the workstations can identify the products to obtain specific information about each order. In combination with the information about the surrounding CPS the whole production process can be adapted and optimized to enhance the value stream. Accordingly the rigid structure of the automation pyramid is transformed into a more flexible decentralized control pattern (Fig. 1).

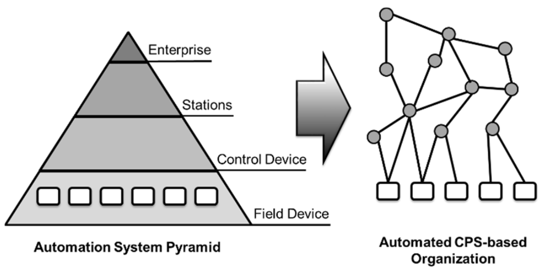

Fig. 1. The usage of cyber-physical systems enables to transform the automation pyramid into a decentralized and interconnected control system [4].

Thereby the decentralized control system with autonomous CPS can adapt the processes to each individual order, thus enabling custom tailored products at low expenses. Furthermore the concept provides additional benefits and capabilities. All information about the production process can be stored and used for the optimization of subsequent processes [5,6]. Additionally the interconnectivity combined with the stored information can be used for the following steps of the product life cycle and enable new service-oriented business models [7].

2. State of the art

Because of the lack of consistent standards, currently there is a huge amount of devices and technologies labeled CPS, embedded systems (ES) and Internet of Things (IoT). The transition between the different categories is often seamless, thus the differentiation mostly depends on their purpose. The term CPS is widely used for industrial devices with the ability to access other CPS and process complex information, thus allowing for a less restricted and more autonomous adaptability than common control systems and ES [6]. In contrast the term IoT is generally used for industrial and private devices, which explicitly connect to the Internet and web services. Nonetheless it is beneficial to define the CPS as the general term, while considering IoT and ES as subgroups, thus emphasizing their specific capabilities [8]. The fundamental requirement for an efficient production process based on CPS is the interoperability, thus ensuring the bi-directional information flow by CPS of different manufacturers [9]. This presupposes the standardization of the communication interfaces and data formats. Because of the vast variety of CPS, standardizations are generally very difficult. To develop and support standardized interfaces, numerous association are working together e.g. the Advanced Manufacturing Partnership 2.0 of the American Government, Plattform Industrie 4.0 of the German government and the Industrial Internet Consortium (IIC) supported by numerous industrial enterprises [7,8]. Furthermore the World Wide Web Consortium (W3C) increasingly supplies standards for IoT. The main focus of the IIC consortium lies on the general industrial usage of the internet, including in transportation, energy, healthcare and manufacturing. Industrie 4.0 on the other hand predominantly focuses at the manufacturing processes and closely related areas [10]. For the definition of compulsory standards the Plattform Industrie 4.0 specifies a new industrial subgroup of CPS [11].

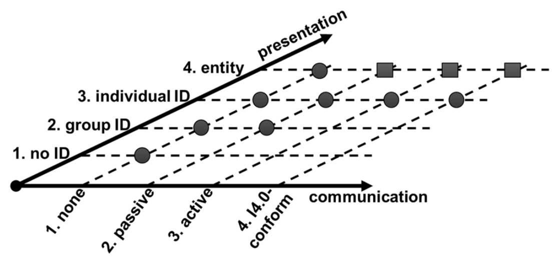

Fig. 2. The categorization of CPS (round dots) and I4.0-components (square dots) according to the Plattform Industrie 4.0 [11].

To define which category of CPS fulfills the requirements, two characteristics must be considered. The first characteristic describes the ability of the CPS to communicate with its environment whereas the second describes how it is presented and whether it can be identified by other CPS. While the