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Consistent data usage and exchange between virtuality and reality to manage complexities in assembly planning

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Abstract

This paper presents a method and practical application for a consistent data exchange between the virtual planning and the real production environment in cyber-physical assembly planning. In the virtual planning environment, the product's ability to be assembled is validated by comparing the product's requirements with the assembly module's capabilities. The information of this comparison is reused for the assembly of the product in reality, where the product requests services from different assembly modules. Changes to the assembly system configuration are identified in reality and the data of the model is updated in the virtual planning environment. Due to the application of the method, the virtual planning model is kept updated and assembly planning results are used in reality for the product assembly process.

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1. Introduction and state of the art

Shorter product life cycles with the trend to customized products are two major challenges for production companies [1]. To satisfy individual customer preferences the number of product variants is continuously growing, whereas new products are put on the market more frequent and in shorter time intervals [2]. Especially the assembly, as the final section of the production before the product is shipped to the customer, is affected by these developments [3]. These developments result in an increasing complexity which needs to be handled when the assembly systems are planned and operated because the systems have to produce a high variety of products [4], [5].

From the technical side, reconfigurable assembly systems are used in order to react flexibly to changing capacity and produce multiple product variants on a single assembly line [6]. The reconfigurable assembly system consists of different modules that have specific assembly capabilities, which contribute to accomplish specific assembly processes [7]. In the context of integrated industry, the mechatronic assembly modules can also be considered as embedded systems gathering physical data via sensors and react via actuators to physical processes in form of cyber-physical systems (CPS) [8]. On the shop floor in the factory, several CPS are combined to a cyber-physical assembly system (CPAS). The innovative aspect of these systems is the integration in digital networks by accessing world-wide available data and services [9]. Thereby, these mechatronic modules execute assigned tasks (assembly processes). Furthermore, they possess the ability to adapt to specific tasks for a certain product variant and to connect among themselves through network functionality as well as with other layers of the automation pyramid [10].

From the software side, supporting tools of the Digital Factory gain more importance in order to control the wide range of product variants and their information [11]. The aim of Digital Factory is the holistic planning, evaluation and ongoing improvement of all main structures, processes and resources of the real factory in conjunction with the product [12]. Before the model is generated, the product is analyzed in assembly planning and respective assembly processes are

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derived [13]. Which modules are being deployed depends on the assembled product. Therefore, both models from the product and from the assembly system are created in the software tools.

But still an information gap exists between the technical and software side because different information is used in each environment. On the national platform in Germany the Automation Markup Language (AutomationML) consortium is developing a framework based on XML which intends to cover the complete engineering process of a production system on the software side as an exchange format [14]. AutomationML focuses on the development process of automation system engineering and models objects of the automated system in a tree based format. Nevertheless, existing tools of the digital factory do not support the format and have problems integrating the information into a neutral format, which might result in duplicates in that format. Moreover, the product with its assembly operation is not focused and thus only modelled with low granularity which is inadequate for assembly planning. Better opportunities for assembly planning are provided by product lifecycle management (PLM) solutions which use databases to store consistent data and allow access from multiple sides. Neither PLM, AutomationXML, nor other exchange formats, like Systems Modeling Language (SysML), provide the opportunity to make a systematic comparison between digital data and real assembly system condition [15].

Thus, this paper describes a method and application for using the semantical same data between the real and virtual production environment for cyber-physical assembly system planning. To combine the virtual and real world as well as support the planning process, three systems are introduced using the same data in different planning states:

- Virtual planning environment for the comparison of product requirements and module abilities
- Agent based control system for the data transfer and control of different modules in the assembly line
- Measurement system for the identification of the assembly system configuration

2. Motivation to handle complexities and challenges in assembly planning

Due to the increasing number of product variants and shortened product life cycles, the assembly planning faces different challenges. On the one hand the assembly planners have to consider multiple product variants and their specific requirements when they validate if a product can be assembled on the existing assembly line. But during the time of operation, the configuration of the initial assembly line might be modified. Because of the system´s reconfigurability, modules are adapted or new modules are integrated which need to be identified for validation. In order to meet the requirement of shortened product life cycles on the other hand these validations have to be made more often and faster.

To overcome these challenges, the assembly planners need to be supported by using tools of the digital factory and use consistent data between different systems as well as between virtuality and reality. In Figure 1 the concept of consistent information flow and use of information by planning and operating an assembly line is given. First of all the product requirements are gathered in the virtual planning environment where the validation is made whether the product can or cannot be assembled on the existing assembly line. In the next step the product requirements are transferred as assembly data in the real production environment where the product is assembled by requesting service of different modules. Adaptation like changes in the assembly system configuration on the existing assembly system are identified and forwarded into the virtual environment.

The idea of the concept is to have consistent information in the virtual planning and real production environment so the planner is able to work with the latest and only necessary, as well as important, information. Which data and how it is used in different systems is described in the following chapters of this paper.

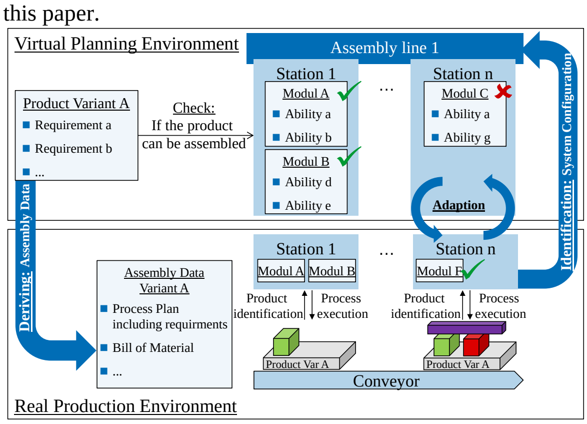

Figure 1: Concept of consistent data usage and exchange in assembly planning

3. Virtual planning environment

Products, processes and the existing assembly line with its modules are modeled in virtual planning [13]. Starting with the bill of material of a product or new product variant the planner has to ensure that the product can be assembled on the assembly line. During planning, parts are assigned to processes which have to be done in assembly to guarantee a functional product at the end of assembly. To perform these processes either a worker or an assembly module (resource) is needed. In addition to the consideration of assembly module abilities, process times, line balancing constraints and other restrictions are considered in the virtual planning environment when multiple product variants are allocated to an assembly line.

The virtual planning environment assists the planner by defining processes and their allocation to assembly stations. This assistance is achieved by an ability-based planning approach and restrictions that have to be considered. The ability-based planning approach allows the comparison of part