Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 61 (2017) 335 – 340
www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

The Digital Twin: Realizing the Cyber-Physical Production System for Industry 4.0

Thomas H.-J. Uhlemann[a]*, Christian Lehmann[a], Rolf Steinhilper[a]

[a]*Fraunhofer Project Group Process Innovation at the Chair of Manufacturing and Remanufacturing Technology, Bayreuth University, 95447 Germany*
* Corresponding author. Tel.: +49-921-785-16323; fax:+49-921-785-16105. *E-mail address:* thomas.uhlemann@uni-bayreuth.de

Abstract

Concerning current approaches to planning of manufacturing processes, the acquisition of a sufficient data basis of the relevant process information and subsequent development of feasible layout options requires 74 % of the overall time-consumption. However, the application of fully automated techniques within planning processes is not yet common practice. Deficits are to be observed in the course of the use of a fully automated data acquisition of the underlying process data, a key element of Industry 4.0, as well as the evaluation and quantification and analysis of the gathered data. As the majority of the planning operations are conducted manually, the lack of any theoretical evaluation renders a benchmarking of the results difficult. Current planning processes analyze the manually achieved results with the aid of simulation. Evaluation and quantification of the planning procedure are limited by complexity that defies manual controllability. Research is therefore required with regard to automated data acquisition and selection, as the near real-time evaluation and analysis of a highly complex production systems relies on a real-time generated database. The paper presents practically feasible approaches to a multi-modal data acquisition approach, its requirements and limitations. The further concept of the Digital Twin for a production process enables a coupling of the production system with its digital equivalent as a base for an optimization with a minimized delay between the time of data acquisition and the creation of the Digital Twin. Therefore a digital data acquisition approach is necessary. As a consequence a cyber-physical production system can be generated, that opens up powerful applications. To ensure a maximum concordance of the cyber-physical process with its real-life model a multimodal data acquisition and evaluation has to be conducted. The paper therefore presents a concept for the composition of a database and proposes guidelines for the implementation of the Digital Twin in production systems in small and medium-sized enterprises.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: *cyber-physical production systems; multimodal data acquisition; digital twin; production system optimization; Industry 4.0*

1. Motivation

In recent years, Industry 4.0 is one of the most prevalent subjects in production engineering. However, methods of industry 4.0 are under-represented within manufacturing operations [1] (p. 7) at this point. This is, on one side, based on non-uniform definitions of Industry 4.0, an issue that current publications counteract against. On the other side, common difficulties as non-existing standards, uncertainties regarding the economical benefits while facing the requirement of sometimes considerable investments [2] (p. 37), as well as the as part of general perception still unsettled matter of data security are apparent [3] (p. 31). Within a 2015 VDMA survey, only 10 % of those surveyed stated to have implemented a comprehensive acquisition of process and machine data. Only a third applied the gained data in a production control feedback [4] (p. 37). Nonetheless, an advantageous use of Industry 4.0 in the course of a value chain cannot be obtained until a vertical implementation of Industry 4.0 in the company itself is ensured [5] (p. 181). Especially the low degree of automation in small and medium-sized enterprises (SME)

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.152

reveals a great requirement for alternative approaches for the realization of a Cyber-Physical Production System (CPPS) [6] (p. 73). Its main aims are to provide and enhance transparency in the production system and allow real-time production control [4] (p. 38), [3] (p. 44), [7] (p. 6). The paper presents a concept for the realization of a Digital Twin of the production system, a core component of Industry 4.0, to assure - providing sufficient data quality - an implementation with minimized investment costs in SME without compromising in matters of the advantages of the Digital Twin and therefore of the CPPS. Herein, an acquisition and transfer of complete set of parameters and data records from production machines is specifically neglected, as this data usually represents the core of competence and expertise of manufacturing companies. A technically feasible solution to data security as part of an inherent approach is introduced. The concept will be implemented in a demonstrator, that proves itself essential for an implementation in SME [3] (p. 35).

2. State of Scientific Knowledge

The following section discusses the state of scientific knowledge regarding the planning of production systems and processes following state of the art methods and simulations.

2.1. Motion Data in Production

The study "Prosense" evinces possibilities to the tracking of products and components in production systems [8] (p. 209), employing the technologies of Beacons and RTLS (real-time locating system). In general, approaches to acquire motion data in production environments are widely limited to RFID (radio-frequency identification) technologies [9] (p. 26). This fact is associated with rather large expenses. Moreover, *Schuh* points out the need for intensified research in the field of real-time localization in production systems as well as the connection to self-optimizing simulation environments [8] (p. 209). Though being desirable, a connection to ERP-systems (Enterprise-Resource-Planning) is regarded as unrealistic for reasons of insufficient standardization [8] (p. 209). Furthermore, ERP-systems mostly rely on manual data inputs that are prone to errors. The extraction of a reliable data source from stock data has no or little prospects of success [8] (p. 209). Motion data is still collected mainly manually [9] (p. 26), even though the potential of automated motion data acquisition for the optimization of production processes is being recognized [10] (p. 35). Concepts exceeding the use of RFID etc. for the localization of objects and personal are subject to ongoing research [11]. Commercial solutions are available and in use [12].

2.2. CPPS

The Cyber-physical Production System is a core component of Industry 4.0 [9] (p. 3). The Digital Shadow and therefore the Digital Twin represents the prerequisite for the development of a CPPS, allowing centralized analysis and control of the production process [9] (p. 31). A useful provision of data, that were acquired for the development of the Digital Twin, requires a cloud-based solution to ensure a near real-time processing [9] (p. 32). Location-independence and remote accessibility of the data provision is an essential criterion for the development of a CPPS [13] (p. 26). To conduct the complex interpretation, a continuous assessment with specialist knowledge is necessary, while a simple transfer of concepts and a non context based data analysis is not promising [14] (p. 98).

2.3. Factory and Production System Planning

Regardless of the degree of automation of single branches and manufacturing companies, a significant increase of the planning expenses has to be noted. [3] (p. 23). Production System Planning can no longer be seen as an only initial planning project. Instead, a continuous production system planning is predominant [15] (p. 14), [16] (p. 18). Manual data acquisition and variation as part of the layout planning contribute up to 74 % of the overall time consumption during the planning process [17] (p. 357), thus conflicts with the requirements of near real-time optimization cycles [18] (p. 19). Traditional methods of process and production planning [17] do not fulfill the demands of near real-time optimization and cannot process the real-time acquired data as a planning basis in a satisfying manner [18] (p. 20). Recently published approaches concerning the cross linking of real and virtual systems examine for example the 3D-imaging of the production system [19] (p. 133). Further investigations focus on special branches or even single production machinery [19] (p. 173,151), that, however, is not in accordance with the aim of branch interdisciplinary solutions for SME [5] (p. 178), and, therefore, is not suitable for an a general assessment of control and continued development of production systems.

2.4. Simulation-based Production Optimization

For years, simulation has been used successfully to solve optimization problems within production and logistic systems [20] (p. VII), [21] (p. VIII). Herein, it has to be noted, that a simulation is not equivalent to an optimization, as the parameter have to be defined and the proposed by the user and solutions have to be evaluated afterwards [17] (p. 377). Consequently, the process of generating varieties is slowed down. A coupling between simulation and optimization is subject to current research. The first approach is formed by the currently prepared VDI 3633, Paper 12. It presents the following coupling approaches:

- simulation to follow optimization
- optimization to follow simulation
- optimization is incorporated into simulation
- simulation is incorporated into optimization

Generally, the foundation of a simulation model is formed by a transfer of the as-is state or planning state [17] (p. 376), to, finally, verify and validate the model using suitable