Editorial

Cyber-Physical Production Systems (CPPS): Introduction

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Digitalization is a major change driver in manufacturing and is nowadays typically linked to terms like Industry 4.0, Smart Manufacturing, or Industrial Internet. Many technologies, methods, and tools are associated with this so called “4th Industrial Revolution”. Examples are the Internet of Things (IoT), cloud computing, additive manufacturing, virtual and augmented reality, big data, or machine learning/artificial intelligence. However, cyber-physical (production) systems (CPPS) as a more overarching concept can be seen as a core element in these developments. Cyber-physical production systems stand for the establishment and continuous application of digital (cyber) representatives of (physical) production related objects in order to improve their design/planning or operation. Based on data acquisition with appropriate time and spatial resolution, those digital models (e.g., based on machine learning, finite element modeling, agent-based modeling) are kept updated. They provide advanced capabilities (e.g., prediction, parameter optimization, root cause analysis) that can finally be used for decision support or even autonomous control functionalities. Digital twin or digital shadow are other terms that are strongly linked to this general idea.

While the technological opportunities are given nowadays, one major challenge is to bring different CPPS elements together into comprehensive solutions that actually lead to measurable benefits for future manufacturing. In general, CPPS can be applied to different factory levels, ranging from single production machines, equipment belonging to technical building services (e.g., heating, ventilation, air conditioning, compressed air generation) or the factory system as a whole. Within those, different application fields can be distinguished like support of the processing and maintenance, but also quality or energy management. Many approaches can be found in research that are actually interesting and important, but just cover single elements and not their embedment into viable systems. The Special Issue “Cyber Physical Production Systems” aims at contributions that show different CPPS elements and their interaction within dedicated fields of action. It finally contains eight quite different approaches that cover a wide range of applications from both the individual factory object as well as system perspective:

- Engelmann et al. [1] presented a technical CPPS setup that aims at supporting the operation of production machines—more transparency is achieved here through an automated state recognition with machine learning as a base for OEE (overall equipment effectiveness) calculation.
- Hürkamp et al. [2] used a combined approach of FEM (finite element method) simulation and machine learning to establish a process related CPPS that allows for the inline prediction of product properties. This was developed and demonstrated for the case of an overmolding process in composite structure manufacturing.
- Makris et al. [3] focused on robots and suggested an agent-based system setup toward the configuration and coordination of robot cells. While using real time data, this approach not only supports the planning, but also the operation phase in robot-based manufacturing processes.
- Blume et al. [4] brought CPPS into the domain of technical building services with the example of manufacturing related cooling towers. A data-based approach was used

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here to identify the main influencing factors for cooling tower performance as the base for advanced control.

- Filz et al. [5] introduced the CPPS concept of virtual quality gates that allow for the data-based prediction of product quality properties as not only the basis for improved planning and operation of production processes, but also process chains. Based on an overall framework with different design options, several case studies were shown to demonstrate applicability and potential.
- Farsi et al. [6] focused on an implementation framework and feasibility study for introducing RFID (radio-frequency identification) and connected digital models into process chains. A multi-agent simulation with predictive capabilities was used to support the planning and potentially also the operation of these setups.
- Sobottka et al. [7] presented a simulation-based approach that allows for an energy aware scheduling of heat treatment furnaces in a casting company. While using data from the company's enterprise resource planning (ERP) and manufacturing execution system (MES), an optimized planning of operations was enabled, which led to improved environmental and economic performance.
- Dornhöfer et al. [8] used multi-agent simulation to improve the planning and potentially, when being combined with the most current data from real production, the operation of manufacturing systems.

The contributions of this Special Issue underline the wide range of application fields for different production entities or the factory as a whole. While giving a selective overview of applications, these are obviously just examples and other approaches can be found in research and industrial practice. However, while covering different CPPS elements and a broad application range, this should stimulate further development of promising CPPS solutions to improve future manufacturing.

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