K-09-01

Digital transformation in the food industry - Opportunities, challenges and solution approaches from the perspective of ongoing research projects (#643)

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Short Abstract

Introduction

Digital disruption, industry 4.0, or internet of things are terms that are currently and frequently discussed. The food industry is also undergoing a digital change. Increasing digitalization should lead to better product quality, greater flexibility, stronger networking of value chains and, ultimately, cost and resource savings with higher productivity.

Food production processes have been digitized for a long time. Classical digitization takes place through analog-to-digital or digital-to-analog conversion with machines and systems automated via programmable logic controllers. Networking using fieldbus and data bus systems enables horizontal integration and vertical data exchange with higher-level process control systems, MES solutions, and ERP systems. More or less, many companies are digitally represented in the automation pyramid (see Figure 1 on the left). This classical architecture is in a state of upheaval. Internet technologies allow permanent networking of physical components with virtual services in service-oriented architectures (SOA). They localized in cloud applications complement real-life entities in cyber-physical production systems (see Figure 1 on the right). In order to succeed digitally in the food industry as well, reusable models as digital representatives of production components and processes (digital twins) are required. On the other hand, the communication of physics and cyber must be described via generic information models that ensure structural connectivity as well as functional and semantic interoperability.

The lecture presents completed, ongoing, and planned studies, which can provide models for the digitalization based on concrete case studies of food production and packaging.

Information models and model-driven generation of MES for food plants

In numerous projects together with the food industry as well as the supplying mechanical engineering, manufacturer-independent standardized data interfaces for production facilities and IT systems could be developed. This resulted in the so-called "Weihenstephan Standards" (WS) information model, widely used in the food and beverage industry (e. g. sausage production). The WS specify the data with its semantic to be exchanged. Additionally, a universal communication protocol has been defined, which is currently being replaced by an OPC UA Companion Specification.

The generic WS information model allowed to follow the automatic generation of MES solutions instead of individually programming them for each food production site. Figure 2 visualizes the model-driven approach based on the generic modeling of plants, processes an MES functionality. Its feasibility has been demonstrated in various case studies in the dairy, brewery, and beverage filling industries.

Model-Based Diagnosis for Packaging Lines

In order to develop a customizable solution automatic fault diagnosis, a model-based diagnosis approach has been examined, which allows the automatic generation of diagnosis solutions for individual plants. New first-principle models for the relevant plant components have been developed, numerically validated, and abstracted to qualitative diagnosis models. Based on a commercial diagnosis engine application systems for two real plants and one virtual plant (based on discrete-event simulation) were generated and evaluated (up to 87.1% of compliant diagnosis results).

Energy simulation in food production systems

Another research project focused on modeling and simulation of the electric energy consumption in food packaging. It was assumed that the electric energy consumption of a food packaging machine might be represented by a limited number of discrete energetic states. These depend on the current operating state and indicate constant consumption levels, which were parameterized empirically. The model has been implemented in a simulation environment and combinated with existing material flow models providing the operating state information. Model validation for single machines and a complete line gave satisfactory results. Currently, the state-based modeling approach is extended to complete food production systems and all media and energy types.

Agent-based bottling in lot size 1

In the research project RoboFill, which is currently being completed, the digital representation of an individualized beverage filling process in a multi-agent system is being pursued. The particular aspect of the approach is that not only machine and production equipment but also orders and individual products with their individually desired properties and production targets are represented digitally in agents which are continuously synchronized with the real world. The products represented in agent software are thus enabled to communicate virtually with production services and to control their production themselves decentrally. The agent system was first developed,

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tested, and virtually put into operation based on the physics simulation of the planned production system (see Figure 3). Finally, the real implementation took place in a demonstration plant of a teaching and test brewery, which can produce saleable individual mixed beverages with individually differently printed bottles.

Conclusion

The presented research projects prove that generic modeling approaches will be decisive for the successful digitalization of food production. Equally vital are standardized information models that allow the continuous synchronization of the real and virtual worlds in future cyber-physical food production systems. As challenges for science and practice remain their development, whereby the applicability and usefulness in the medium-sized food industry should be demonstrated in practical reference applications.

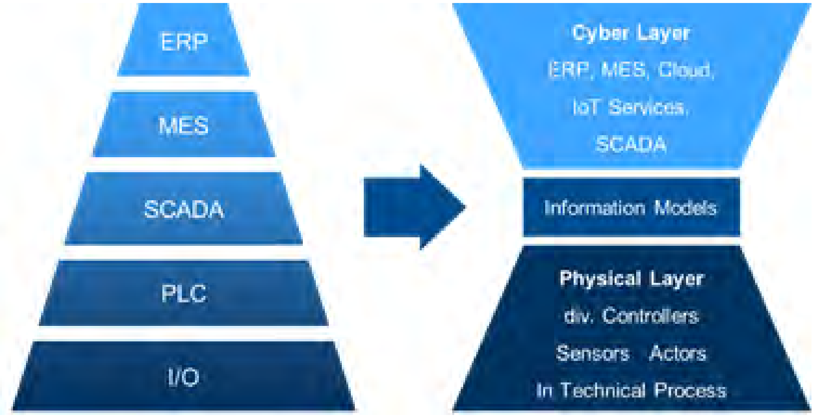

Figure 1:
From Automation Pyramid to Cyber-Physical Production Systems

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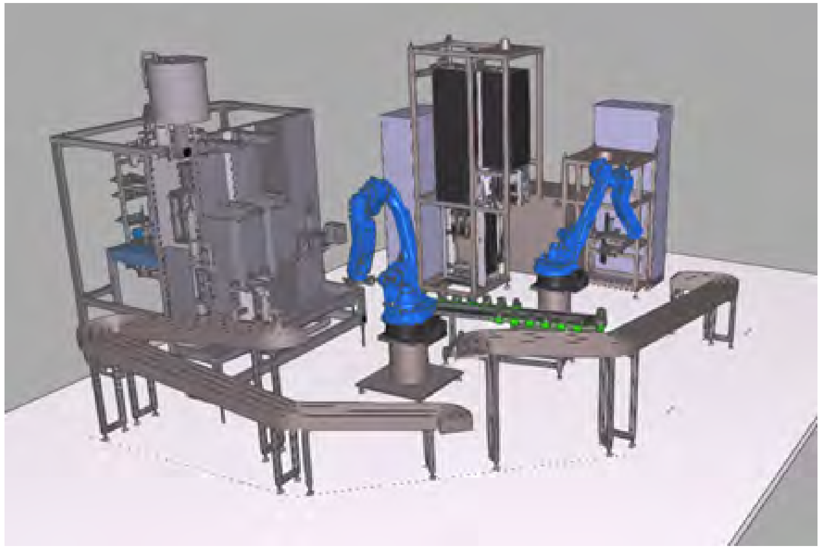

Figure 3:
Physical simulation model of the agent controlled RoboFill system

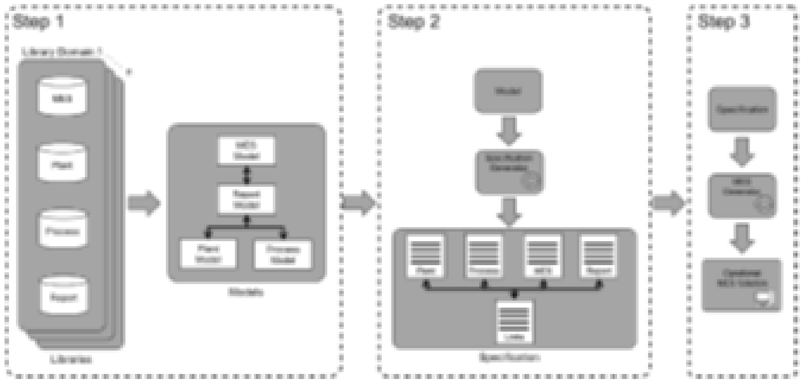

Figure 2:
Overview of the model-driven approach for the automatic generation of MES.

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