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# Towards future Automation Systems in Manufacturing

Abstract –This paper presents latest research approaches in manufacturing automation based on intelligent, flexible and efficient cyber-physical systems. . First, a maturity model is presented aiming to explain the potential steps towards future automation. Secondly, the changes in the engineering process are also considered which would lead to self-adapting or even to autonomous systems. Lastly, an example of a research prototype is depicted in order to discuss some of the present hurdles of the practical application.

*Keywords: cyber physical production systems, maturity model, information management, smart factory*

**Introduction**. The term Cyber-physical systems was conceived in the field of automation technology around 2006 by [Lee]. Cyber-physical systems are by definition a combination of the physical assets of a real plant and the world of data, information and software, forming the cyber aspect.

In today's manufacturing systems, a very large diversity of e.g. hundreds of subsystems exists as there are multiple manufacturers who integrate their systems with the subsystems of others. This results in an ongoing complexity of such systems making it very difficult to manage. The operation of such large scale systems demands for standardization, be it classification schemas for components and their grouping, information models etc. This is very much required as the linkage of components in Hard- and Software is extensive. A change or update in one instance of a domain, e.g. a mechanical hardware device, may trigger multiple updates in other areas, such as in the electronics or software.

As a result, the automated manufacturing systems of today and even more in the future are going to be a composition of software and data, which form a digital twin along with the electronics and mechanical hardware of the physical systems.

**Steps towards the future - a Maturity Model.** Research in Germany has delivered a maturity model for such systems which can address the question on how future developments of automated manufacturing systems can incorporate IT functionality. Fig 1 depicts a fusion of the research in [1, 2]. The maturity model outlines the five steps towards a new generation of self-optimizing and self-acting automation systems, which entail a large degree of autonomy.

For starters, automated manufacturing systems would be "connected", i.e. be composed of networked components which can exchange data with each other. In the next step, a visibility of data is available, which is based on the perception with sensors. Further in a third step, a transparency of the manufacturing processes can be achieved by functions of interpretation and recognition. These three steps can be seen as an acquisition of data and their systematic analysis. Further evaluation steps of these data following the concepts of

Artificial intelligence are also feasible. The interpretation and recognition of data can be done in various levels of complexity. For instance, a predictive simulation can be utilized to project multiple scenarios in the future. Such a prognosis based on analytics and simulation would form a forth step.

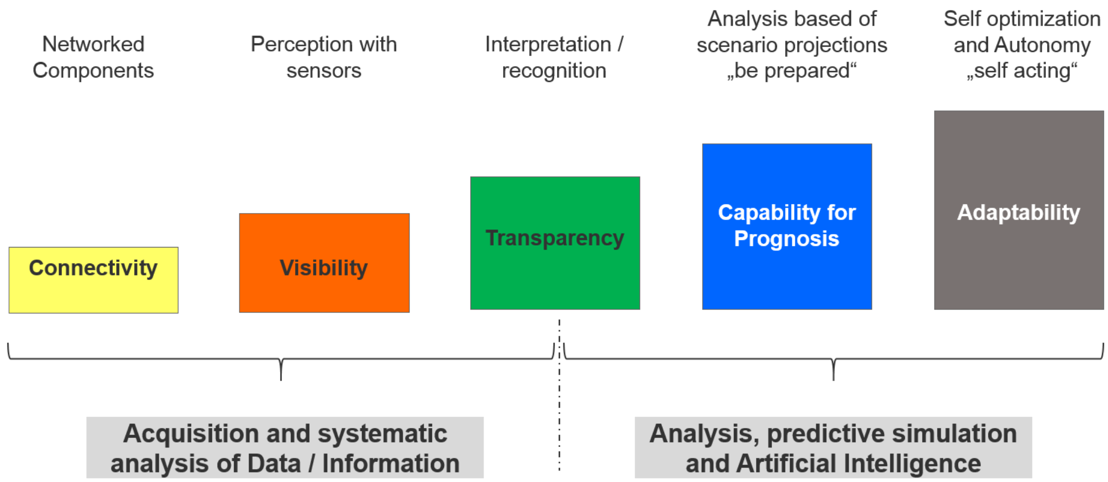


Fig. 1: A Maturity Model for Cyber-physical Production Systems and associated IT functionality

The last/fifth step which is most advanced would be a fully adaptable manufacturing system. Such systems of the future could be self-optimizing or even self-acting. The aspect of self-Adapting or even autonomous functionality is an important topic in research, despite the fact that a fully autonomous system having control over its own activities, might sound far-fetched.

**State-of-the-art.** It was evident in research in the early 2000 (see for instance [3]) that the networking of physical assets results in a large diversity of data. A swarm of sensor systems capturing all types of information, stored in a cloud infrastructure accessible by mobile devices anywhere has become a reality today. Machine-to-machine communication systems, the “cloud” or internet-of-things (IoT) operating systems are available in terms of commercial products. Furthermore, the product lifecycle of management activities have resulted in large Engineering backbone systems.

Due to the availability of these products, research questions evolve from a plain technical feasibility to the question of how to master the tremendous complexity of software systems and their data. Obviously the question is how the step toward cyber-physical systems can be made, which assists a hybrid of “cyber” e.g. the information world and the “physical” world of hardware. [3, 4]. A physical system and its cyber part are created in unison forming a digital twin. The characteristics and functionalities of physical assets are pictured by a digital twin along the lifecycle. A full integration of cyber-physical systems and availability of a digital twin, i.e. a cyber representation which could be managed in a cyber or physical way is however, still a vision.

**Future engineering - design moves to runtime.** As Figure 3 illustrates the present engineering process as of to dateis rather sequential and runs through the phase of engineering, commissioning and test until the operation and runtime of production starts. In some cases a retrofit might be an eventual stage in which the manufacturing is being rebuilt, prior to the start of a new operational phase.

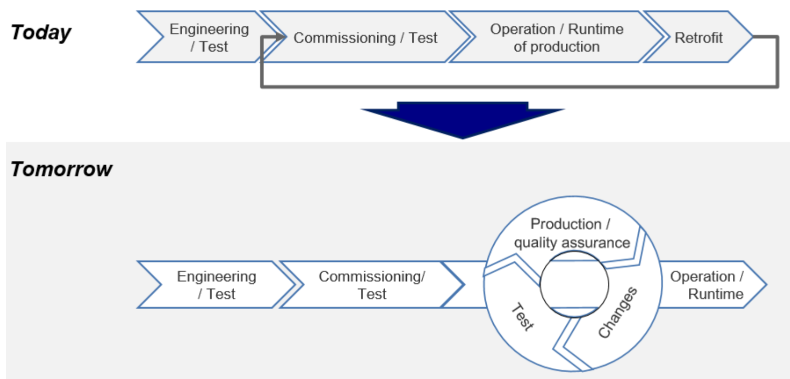


Fig. 3: Design moves to runtime in which changes are omnipresent

This means that once the production has commenced, a change of the system might be normal leading to a situation in which new products could easily be manufactured as the manufacturing would change in that way. Consequently, this implies an enormous paradigm shift as a continuous change is the normal mode of operation.

**-Examples of Cyber-physical Systems for Application in Manufacturing.** An illustration of the usage of Cyber-physical systems based on examples of research work is presented in Fig. 4 in which an assessment system of various automation levels [2] is also indicated. This system has already far-reaching capabilities in automatic networking and self-adapting to changing requirements. A detailed description can be found in [4, 5, 6]

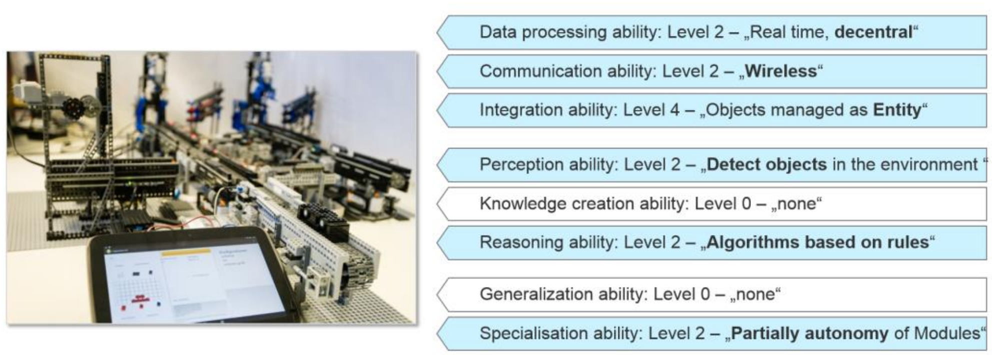


Fig. 4: Example of an automated Manufacturing of a lego model Car (see [2] for further elaboration

The concept of this prototype is an upside down change of the control paradigm as the product deploys the resources and steers its way through the manufacturing. Thereby the individual manufacturing models are represented by networked agents who negotiate the schedule based on product requests.

**Hurdles in the practical implementation:** As it becomes evident from the interaction with experts in the field, the following issues have been raised and need attention to tackle the next levels in manufacturing automation:

- Improved techniques are required for establishing the communication between the components of the cyber-physical systems in order to reduce the effort for interoperability.
- New types of standards, e.g. for the semantic processing of information, are required but are difficult to conceive.
- Means to manage the complexity of very large automation systems are yet to be invented.
- The topics of analytics, machine learning and artificial Intelligence need to be deployed to enable Self-X functionalities and present limitation in automatic adjustment of systems.

The outcome of the fulfilment of these aspects, a new way of how assets of the physical world are working with their cyber part, would pave the way for future deployment of artificial intelligence.

**Conclusion.** This paper presents a viewpoint on the present developments of Cyber - physical production systems and discusses future steps. For this purpose, a maturity model for automated manufacturing is presented and discussed with respect to the future engineering of such systems. An example of an automated model plant is provided Ato explain some of the present hurdles for practical application of these concepts in the coming years.

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