Industry 4.0

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1 Application-Pull and Technology-Push as Driving Forces for the Fourth Industrial Revolution

Industry is the part of an economy that produces material goods which are highly mechanized and automatized. Ever since the beginning of industrialization, technological leaps have led to paradigm shifts which today are ex-post named "industrial revolutions": in the field of mechanization (the so-called 1st industrial revolution), of the intensive use of electrical energy (the so-called 2nd industrial revolution), and of the widespread digitalization (the so-called 3rd industrial revolution). On the basis of an advanced digitalization within factories, the combination of Internet technologies and future-oriented technologies in the field of "smart" objects (machines and products) seems to result in a new fundamental paradigm shift in industrial production. The vision of future production contains modular and efficient manufacturing systems and characterizes scenarios in which products control their own manufacturing process. This is supposed to realize the manufacturing of individual products in a batch size of one while maintaining the economic conditions of mass production. Tempted by this future expectation, the term "Industry 4.0" was established ex-ante for a planned "4th industrial revolution", the term being a reminiscence of software versioning.

Decisive for the fast spread was the recommendation for implementation to the German Government, which carried the term in its title and was picked up willingly by the Federal Ministry of Education and Research and has become an eponym for a future project in the context of the high-tech strategy 2020. Currently an industrial platform consisting of three well-known industry associations named "Industry 4.0" is contributing to the dispersion of the term. Outside of the German-speaking area, the term is not common.

In this paper the term "Industry 4.0" describes a future project that can be defined by two development directions. On the one hand there is a huge application-pull, which induces a remarkable need for changes due to changing operative framework conditions. Triggers for this are general social, economic, and political changes. Those are in particular:

- Short development periods: Development periods and innovation periods need to be shortened. High innovation capability is becoming an essential success factor for many enterprises ("time to market").
- Individualization on demand: A change from a seller's into a buyer's market has been becoming apparent for decades now, which means buyers can define the conditions of the trade. This trend leads to an increasing individualization of products and in extreme cases to individual products. This is also called "batch size one".
- Flexibility: Due to the new framework requirements, higher flexibility in product development, especially in production, is necessary.
- Decentralization: To cope with the specified conditions, faster decision-making procedures are necessary. For this, organizational hierarchies need to be reduced.
- Resource efficiency: Increasing shortage and the related increase of prices for resources as well as social change in the context of ecological aspects require a more intensive focus on sustainability in industrial contexts. The aim is an economic and ecological increase in efficiency.

On the other hand, there is an exceptional technology-push in industrial practice. This technology-push has already influenced daily routine in private areas. Buzzwords are Web 2.0, Apps,

Smartphones, laptops, 3D-printers, etc. However, in job-related, especially in industrial contexts innovative technologies are not widely spread. Therefore, extensive approaches of a technology-push can be identified:

- Further increasing mechanization and automation: In the work process more and more technical aids will be used, which support physical work. Furthermore, automatic solutions will adopt the execution of versatile operations, which consist of operational, dispositive and analytical components such as "autonomous" manufacturing cells which independently control and optimize manufacturing in various steps.
- Digitalization and networking: The increasing digitalization of all manufacturing and manufacturing-supporting tools is resulting in the registration of an increasing amount of actor- and sensor-data which can support functions of control and analysis. Digital processes evolve as a result of the likewise increased networking of technical components and, in conjunction with the increase of the digitalization of produced goods and services, they lead to completely digitalized environments. Those are in turn driving forces for new technologies such as simulation, digital protection or virtual resp. augmented reality.
- Miniaturization: Simultaneously there is a trend towards miniaturization. While computers required significant space some years ago, nowadays devices with a comparable or even considerably better performance can be installed on few cubic centimeters. This enables new fields of application, especially in the context of production and logistics.

The drafted developments are well-known in detail but in total there is the potential to turn around the industrial practice comprehensively.

2 Fundamental Concepts

The term Industry 4.0 collectively refers to a wide range of current concepts, whose clear classification concerning a discipline as well as their precise distinction is not possible in individual cases. In the following fundamental concepts are listed:

- Smart Factory: Manufacturing will completely be equipped with sensors, actors, and autonomous systems. By using "smart technology" related to holistically digitalized models of products and factories (digital factory) and an application of various technologies of Ubiquitous Computing, so-called "Smart Factories" develop which are autonomously controlled (Lucke et al. 2008).
- Cyber-physical Systems: The physical and the digital level merge. If this covers the level of production as well as that of the products, systems emerge whose physical and digital representation cannot be differentiated in a reasonable way anymore. An example can be observed in the area of preventive maintenance: Process parameters (stress, productive time etc.) of mechanical components underlying a (physical) wear and tear are recorded digitally. The real condition of the system results from the physical object and its digital process parameters.
- Self-organization: Existing manufacturing systems are becoming increasingly decentralized. This comes along with a decomposition of classic production hierarchy and a change towards decentralized self-organization.
- New systems in distribution and procurement: Distribution and procurement will increasingly be individualized. Connected processes will be handled by using various different channels.
- New systems in the development of products and services: Product and service development will be individualized. In this context, approaches of open innovation and product intelligence as well as product memory are of outstanding importance.
- Adaptation to human needs: New manufacturing systems should be designed to follow human needs instead of the reverse.
- Corporate Social Responsibility: Sustainability and resource-efficiency are increasingly in the focus of the design of industrial manufacturing processes. These factors are fundamental framework conditions for succeeding products.

Figure 1 visualizes the consequences of an extensive integration of different components into the supply chain of Industry 4.0. The cyber-physical production network is particularly characterized by autonomous actions independent from the location, widespread integration, various automated services, and by its ability to react context-specifically to the customers' needs and requirements. Among the different protagonists, manifold informational interrelations and interdependencies exist.

3 Relevance for Business and Information Systems Engineering and Exemplary Fields of Application

The approaches and ideas in the context of "Industry 4.0" are situated at the interface of the disciplines electrical engineering, business administration, computer science, business and information systems engineering, and mechanical engineering as well as the participating segments. The illustrated parts of Industry 4.0 result in general fields of activity, which are of particular interest for the discipline of business and information systems engineering (BISE).

A closer look at the first areas of application and branches that were of interest for the discipline of BISE shows that industry was often focused (e.g., Hasenkamp and Stahlknecht 2009, p. 16). The discipline of BISE has indeed opened itself up towards other branches and areas of application, however integrated information systems and their modeling and design still play a central role. Accordingly, the discipline of BISE can build upon established results.

For the discipline of BISE interesting starting points arise especially concerning the area of integration in the context of "Industry 4.0" (Fettke 2013):

- Integration of the physical basic system and the software system: New options by using real-time information via RFID, sensors etc. allow an advanced integration in various application systems.
- Integration with other branches and economic sectors: Reflection on integrative concepts with other branches is necessary. Thus, especially commerce, logistics, but also financial services and other service providers play a central role.
- Integration with other industries and industry types: Although the discipline of BISE knows different types of plant, it remains unclear how the change between different types of plant can be supported adequately with information technology.
- Integration in dynamic value-creation networks: Consideration of value-adding processes gains new aspects
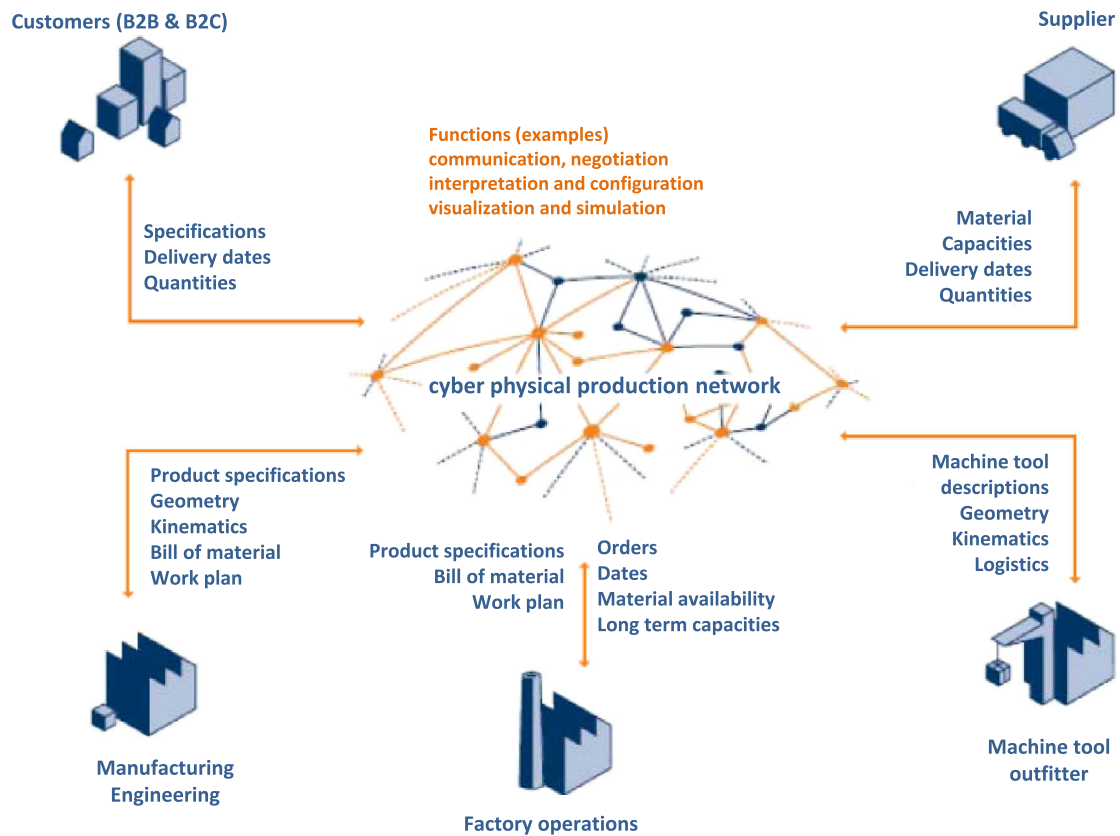
Fig. 1 Example for interdependencies of a supply chain in the context of the future project "Industry 4.0" (Geisberger and Broy 2012, p. 56)

in the context of Industry 4.0 if production is carried out in dynamic networks over the whole product-lifecycle (product service systems). At this point it is essential to develop adequate concepts which consider production under aspects of complementary and substituting network partners.

Against this background, new issues concerning the discipline of BISE appear in the era of Industry 4.0 with regard to an appropriate degree of integration, automation and decentralization of enterprise information systems.

Furthermore, multifaceted areas of application concerning the discipline of BISE have already come into existence, some of which will be exemplarily outlined in the following:

- Methods of modeling and reference models: New concepts within Industry 4.0 lead to a demand concerning advanced methods of modeling and specific reference models (Fettke and Loos 2004).
- Innovative MES/ERP approaches: Single scientific studies examine innovative concepts for Manufacturing Execution Systems (MES) and Enterprise

Resource Planning Systems (ERP) (see Klöpper et al. 2012; Koch et al. 2010).

- Business Intelligence: Based on the use of quantitative methods of Business Intelligence, initial concepts and models have already been developed and evaluated (Gronau 2012; Lasi 2012).
- Digital product memories: These systems allow for a collection of data records in all phases of product lifecycle, they additionally save them and distribute them for analysis. This covers data of individual production, assembling, distribution etc. (see Brandherm and Kröner 2011).
- Developing methodology: In Industry 4.0 innovative methodical approaches for planning and development of manufacturing systems are required. For instance, Pohlmann (2008) and Loskyll (2013) each describe particular methodical concepts for planning, regulating, and controlling services in a factory, which meet the demands of the newest technological possibilities and requirements.
- Innovative platform architectures: Wahlster (2014) asserts that future manufacturing systems will be based

on an innovative platform that bundles intelligent products, data, and services, and makes them consistently usable.

- Data models and exchange formats: New manufacturing technologies such as Additive Manufacturing lead to new requirements in the fields of data models and data exchange formats (Lasi et al. 2014). This concerns engineering-oriented application systems as well as application systems for business administration.

4 Summary and Expected Trends

In summary, it can be concluded that the term "Industry 4.0" describes different – primarily IT driven – changes in manufacturing systems. These developments do not only have technological but furthermore versatile organizational implications. As a result, a change from product- to service-orientation even in traditional industries is expected. Second, an appearance of new types of enterprises can be anticipated which adopt new specific roles within the manufacturing process resp. the value-creation net-

works (Scheer 2012). For instance it is possible that, comparable to brokers and clearing-points in the branch of financial services, analog types of enterprises will also appear within the industry.

With the planning, analysis, modeling, design, implementation and the maintenance (in short: the development) of such highly complex, dynamic, and integrated information systems, an attractive and at the same time challenging task for the academic discipline of BISE arises, which can secure and further develop the competitiveness of industrial enterprises.

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