by Rainer Drath and Alexander Horch

Industrie 4.0: Hit or Hype?

In Germany, the term *Industrie 4.0* [1] is currently prevalent in almost every industry-related fair, conference, or call for public-funded projects. First used at the Hanover Fair in 2011, the term, raised numerous discussions, and the major question is: is it a hit or hype? Even in politics, this term is used frequently with respect to German industry, and research efforts relating to it are currently supported by €200 million from government-funding bodies—the German Federal Ministry of Education and Research and the German Federal Ministry of Economic Affairs and Energy. The term Industrie 4.0 refers to the fourth industrial revolution and is often understood as the application of the generic concept of cyberphysical systems (CPSs) [5]–[7] to industrial production systems (cyberphysical production systems). In North America, similar ideas have been brought up under the name *Industrial Internet* [3], [4] by General Electric. The technical basis is very similar to Industrie 4.0, but the application is broader than industrial production and also includes, e.g., smart electrical grids. The various definitions have caused confusion rather than increasing transparency. Overambitious marketing reinforced the confusion (Industrie 4.0 is already being done). This obscures the real and sound future visions behind Industrie 4.0. This column is intended to provide easy-to-understand access to the core ideas of Industrie 4.0 and describes the basic industrial requirements that need to be fulfilled for its success.

FUTURE NAVIGATION SYSTEMS COULD CALCULATE AN OPTIMAL ROUTE THROUGH TRAFFIC FOR EVERY CAR, DEPENDENT ON ITS POSITION, DESTINATION, AND OTHER RELATED INFORMATION, SUCH AS TRAFFIC JAMS.

Industrie 1.0–3.0

The first three industrial revolutions spanned almost 200 years. First, mechanical looms driven by steam engines in the 1780s started a significant change. Fabric production left private homes in favor of central factories, followed by an extreme increase in productivity. The second industrial revolution began about 100 years later in the slaughterhouses in Cincinnati, Ohio, and found its climax with the production of the Ford Model T in the United States. The development of continuous production lines based on both division of labor and the introduction of conveyor belts resulted in another productivity explosion. Third, in 1969, Modicon presented the first programmable logic controller that enabled digital programming of automation systems. The programming paradigm still governs today's modern automation system engineering and leads to highly flexible and efficient automation systems (Figure 1).

It is remarkable that Industrie 4.0 announces an industrial revolution a priori. In that sense, the somewhat

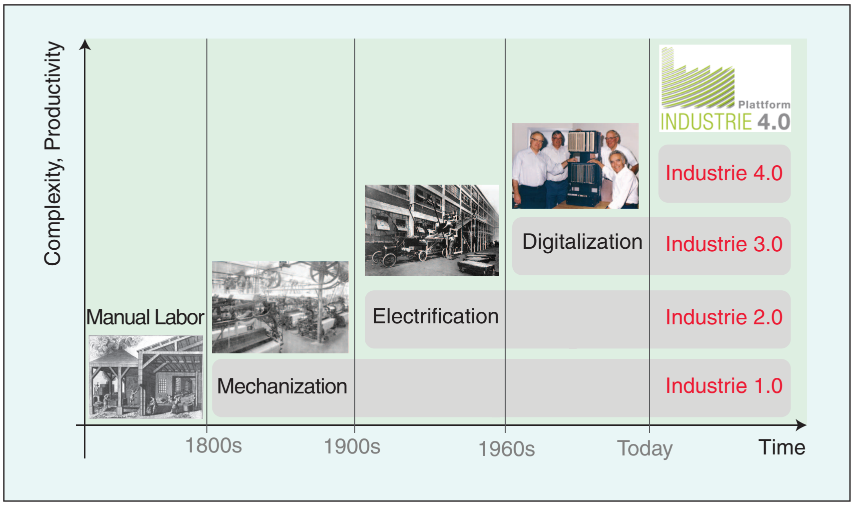

FIGURE 1 – An overview of the four industrial revolutions. Note that production flexibility was highest when manual labor dominated production. Flexibility is one of the main drivers behind Industrie 4.0. [Images courtesy of Archive City of Murg, Germany, http://commons.wikimedia.org/wiki/File:Aline1913.jpg, and Control Engineering Asia (www.ceasiamag.com).]

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provocative question "hit or hype" illustrates the current discussion but cannot be answered yet; it is the future. However, we believe that the ideas behind Industrie 4.0 have the potential to be as formative as the previous three technical breakthroughs.

Industrie 4.0—Background and Technical Drivers

The major technical background of Industrie 4.0 is the introduction of Internet technologies into industry. This technical basis is often mixed with corresponding future visions. Despite some overeager marketing messages, Industrie 4.0 is still in the future. Most of the technical ingredients are already available, although they are mainly used in other applications, e.g., the consumer industry.

Industrie 4.0 is closely related to CPSs. The following hypotheses will help in understanding the CPS concept.

- *Hypothesis 1*: Communication infrastructure in production systems will become more affordable and, hence, be introduced everywhere. It is useful for various purposes such as engineering, configuration, service, diagnostics, operation and service of products, field devices, machines, or plants. It will become a self-evident part of future production systems. This trend is unstoppable and not forced by anybody—it is currently happening, the same way mobile phones have found their way into our pockets.
- *Hypothesis 2*: Field devices, machines, plants, and factories (even individual products) will increasingly be connected to a network (e.g., the Internet or a private factory network). They will be available as data objects in the network and may store real-time data. Therefore, they become searchable, explorable, and analyzable in the network. This will lead to an explosion of available objects and data, accessible from anywhere.
- *Hypothesis 3*: Field devices, machines, plants, and factories (even individual products) will become able to store documents and knowledge about themselves outside their physical body in the network. By doing so, they obtain a virtual living representation in the net, with individual identifiers. They will store documents, three-dimensional (3-D) models, simulation models, requirements, etc. This information, stored outside the body of the physical objects, is updatable and, hence, represents the latest available version. In addition to those data, different functionalities will act for the physical objects: negotiation functions, exploration functions, etc. These data objects augment the corresponding real device and form a second identity in the network, where these data objects form a knowledge base for various applications.

INDUSTRIE 4.0 IS A POTENTIAL HIT, GIVEN THAT ALL CONTRIBUTING PARTIES COLLABORATE WELL TO OVERCOME THE CHALLENGES.

These three hypotheses sound reasonable, but to make their connection more transparent, let us consider a simple example: traffic lights today either act independently from each other or are controlled by a central traffic control system. As a CPS, the physical traffic lights would have an object representation in the network providing their current color and time schedule. Based on these data, future cars could inform themselves about the plan of the next traffic light, adjust speed, or provide automatic motor on–off features to minimize emissions. Future navigation systems could calculate an optimal route through traffic for every car, dependent on its position, destination, and other related information, such as traffic jams.

Once cars feed their position, speed, and destination back into the network, the traffic lights could orchestrate and optimize their behavior with respect to an optimal traffic flow. Police, ambulances, or fire engines could control green lights for optimal security and safety in the city.

The novelty in such a scenario is not in a new technology, but in that it combines the available technology in a new way. The availability of bulk data allows the development of services that have not been possible so far, like navigation systems with user-driven traffic information. The availability of bulk data allows various new business models. In combination with third-party services such as weather, calendar, payment services, geolocation, or historical data, new levels of organization and scheduling are possible. The possibilities are endless.

To sum it up, a CPS requires three levels (see Figure 2):

- the physical objects (in this example, the traffic lights and cars)
- data models of the mentioned physical objects in a network infrastructure
- services based on the available data.

What would be possible in an industry based on this concept? Components, products, and other entities in industrial production would get their own identities in the network. They could negotiate with each other or could be interconnected and simulated. Systems could be virtually integrated, tested, and optimized. The digital factory and the virtual commissioning would be accessible to everybody (authorized). Algorithms for autonomy optimization

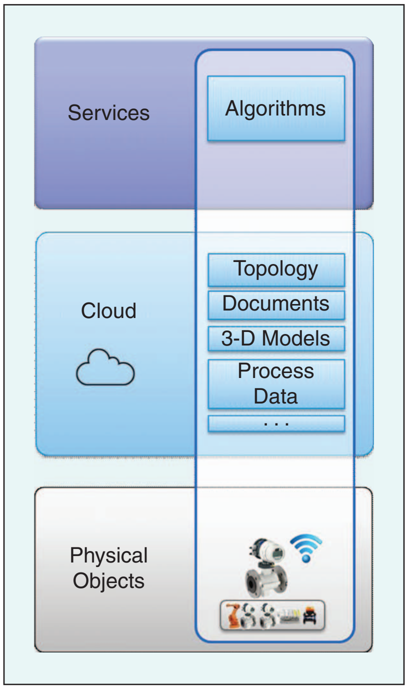

FIGURE 2 – Three levels form a CPS in Industrie 4.0.

could revolutionize production planning. Products could navigate autonomously through the production line. The revolution is not necessarily the technical realization but the new horizon of business models, services, and individualized products.

Industrial Requirements

The German Industrie 4.0 initiative is supported by an industry-led steering group, which coordinates various committee teams [9]. Many companies, organizations, and universities work on different aspects of Industrie 4.0. Some very basic requirements guide most of the work currently being done.

- *Investment protection*: Industrie 4.0 has to be stepwise introducible into existing plants.
- *Stability*: Industrie 4.0 must not compromise production, neither by disturbances nor by a breakdown. Production systems have fierce demands with respect to real-time behavior, reliability, availability, robustness, etc.
- *Data Privacy*: access to production-related data and services has to be controllable to protect company know-how.
- *Cybersecurity*: Industrie 4.0 has to prevent unauthorized access to production systems to prevent environmental or economic damage and harm to humans.

Any future Industrie 4.0 architecture has to fulfill these requirements as preconditions for industrial acceptance.

The next important steps toward realizing an Industrie 4.0 reference architecture have already been outlined in [2, Sec. 5]. At this level, companies, organizations, and standardization bodies [8] need to collaborate with maximum transparency to succeed in this complex and precompetitive task.

It is difficult to imagine all of the possible consequences of an industrial production that largely follows the concepts shown here. Looking back at the previous industrial revolutions, it was merely the effect of changes in working and production methods rather than technical novelty that has motivated the term *revolution*. What could be revolutionary for people, the economy, and society with respect to Industrie 4.0? Flexibility in production needs to be translated into the flexibility of workers. It needs to take advantage of the demographic challenge in many countries. In addition, it has to enable industrial production to cope with the decarbonization of the energy supply, political instabilities in some countries, natural disasters, shortages of natural reserves, etc. For Industrie 4.0, the term *revolution* does not refer to the technical realization but to the ability to meet today's as well as future challenges.

Summary

Industrie 4.0 is still in the future. However, Industrie 4.0 is a phenomenon that will come inevitably, whether we want it or not. This is similar to the consumer world, which was confronted with the Internet in the early 1990s, leading to an unpredictable world of online shops, auctions, Internet banking, online brokerage, and video streaming. Industrie 4.0 is the triad of physical objects, their virtual representation and services, and applications on top of those. We are convinced that Industrie 4.0 is a potential hit, given that all contributing parties collaborate well to overcome the challenges outlined above. The reader is invited to contribute.

Biographies

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Alexander Horch (alexander.horch@de.abb.com) received his M.Sc. degree in engineering cybernetics from the University of Stuttgart in 1996 and Ph.D. degree in automatic control from Royal Institute of Technology Stockholm, 2000. He worked at ABB Corporate Research Germany as scientist and project leader in the area of optimization and asset management in different process industries. Since 2007, he has held several management roles in the areas of production optimization, industrial and power automation, smart electrical grids, and industrial control systems. He is a certified project management professional and a certified automation professional from ISA. His current interests include the concretization of cyberphysical systems to electrical power systems and industrial production.

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