Editorial

Harald Schöning*

Industry 4.0

https://doi.org/10.1515/itit-2018-0015

The term Industry 4.0 („Industrie 4.0") – even in its German spelling – is nowadays internationally understood as a synonym for the digitization of the industry, combining production with up-to-date information and communication technology. This covers discrete manufacturing (including the production of machines for discrete manufacturing) but also process industry and even agriculture. Industry 4.0 does not just mean that software more and more becomes an indispensable value-creating part of a machine, but targets at improving overall efficiency and quality of the whole value chain. As such, Industry 4.0 covers not only the "Smart Factory", including the communication among machines, between machines and the products they produce, between machines and workers, between shopfloor and back office, but also goes beyond a single factory or company involving all participants of the supply chain (the whole business ecosystem), including the logistics. Industry 4.0 also covers the whole life cycle of a product, from design, production, usage, maintenance to recycling. As a consequence, novel services – the so called "Smart Services" – can be offered by the various actors in the value chain, enhancing existing business by product-related services ranging from predictive maintenance to radically changed business models such as selling services rather than products, e. g. offering the service to produce compressed air on the customer's premises (billed by volume) rather than selling the compressors.

Other aspects of Industry 4.0 comprise batch size 1 (i. e. using the new flexibility to produce individual products in a production line), additive manufacturing, collaborative robots, and usage of augmented reality to assist workers. Autonomy of machines and production lines can even result in machine-to-machine business transactions where machines order services or goods form other machines run by other companies without any human intervention. Design data of machines and products can be used to create digital twins and to simulate production before the real machines exist.

***Corresponding author: Harald Schöning,** Software AG, Uhlandstr. 12, 64297 Darmstadt, Germany, e-mail: harald.schoening@softwareag.com

From this description it should be clear that Industry 4.0 requires an unprecedented collaboration of various disciplines such as mechanical engineering, electrical engineering, economics, law and computer science.

Industry 4.0 is enabled by the fact that machines contain many sensors for all relevant operation parameters, and that machines can connect to a network to transmit these sensor data. Even for older machines, sensors can be added. Thus, machines are converted to nodes in the Internet of Things (IoT), opening its full potential. This typically goes along with computing power at the machine (edge computing) and often extends into a connection to a cloud, with several intermediate computing units (fog computing). The cloud is often used to connect machine producers with the operators of the machines to leverage the power of IoT, e. g. to enable predictive maintenance [1, 2]. Going even further, several industrial platforms arise that based on this interconnectivity offer substantially new services to machine operators, machine producers, and other actors of the value chain [3, 4].

Obviously, core computer science topics such as data analytics, knowledge management, user interfaces, machine learning, communication protocols, scalable architectures, and, of course, cyber security play a major role in Industry 4.0. However, computer scientists have to respect the production context which imposes a lot of constrains that are well understood by mechanical engineers, e. g. real time constraints, safety regulations, or the impacts of a "production down" scenario. Just as an example, when facing a severe cyber-attack, it might be feasible to shut down a computing center. Shutting down a chemical production process or a steel mill, however, can result in a severe economic damage or even in a safety threat for workers. Data from production often allow conclusions about (secret) production procedures and workload of a production line, information that is very valuable for competitors, and hence has to be protected from unauthorized access. In addition, manipulation and obstruction of production by outside attackers must be prevented while at the same time connecting to the internet.

Under the leadership of the German Federal Ministry of Economic Affairs and Energy and the Federal Ministry of Education and Research, the "Plattform Industrie 4.0" [5] brings together researcher and companies from relevant disciplines and sectors to work in an interdisciplinary manner to create guidelines, prepare standards, and give guidance to small and medium enterprises how to adapt Industry 4.0.

In this issue, some examples will show various aspects where computer science adds value to Industry 4.0.

The paper "Digital Twin Technology – An Approach for Industrie 4.0 Vertical and Horizontal Lifecycle Integration" by Reiner Anderl and his co-authors discuss the concept of a digital twin, i. e. a digital representation of a product or machine, and its relation to the Industry 4.0 Component and its Administration Shell as defined by the Plattform Industrie 4.0. They conclude that digital twin technology becomes a key success factor to cyber-physical systems, in particular the tight coupling between digital and physical product over their whole lifecycle.

That even IT disciplines such as business process management that are perceived as being tied to the back office domain can play a crucial role in industry 4.0, is shown by Jana-Rebecca Rehse, Sharam Dadashnia, and Peter Fettke in their paper "Business Process Management for Industry 4.0 – Three Application cases in the DFKI-Smart-Lego-Factory". In a table-sized yet fully functional smart factory, they demonstrate how the whole manufacturing process lifecycle from process strategy and process modeling over process implementation and execution to process monitoring, controlling, and improvement can be covered by process management systems even for Industry 4.0 scenarios. Dedicated aspects of this life cycle are further elaborated: Model-based management of manufacturing processes, process mining for manufacturing processes and prediction for manufacturing processes based on deep learning technologies.

In their article "Blockchain in Industrie 4.0: Beyond Cryptocurrency", Martin Laabs and Siniša Đukanović discuss the benefits of blockchain technology and the related concept of smart contracts to Industry 4.0, in particular for machine-to-machine transactions, and to self-organizing supply chains. They identify typical challenges from Industry 4.0 scenarios and assess the applicability of blockchain concepts to these scenarios. They also discuss how the known blockchain issues such as poor performance and high transactional fee can be addressed and solved in this context.

In "Flexible IT Platform for Synchronizing Energy Demands with Volatile Markets", Paul Schott and his co-authors show how Industry 4.0 allows to reach out to other sectors – in this case the energy market, not only to adapt energy consumption to fluctuating energy cost, but also to create new business models in markets that before had not been addressed by industries. In this case, industries become important players in the energy market, helping to keep power grids stable in the face of more and more volatile energy production by renewable energies. In addition, the approach contributes to sustainable development goals such as climate and affordable and clean energy.

The paper "Efficient and Fast Monitoring and Disruption Management for a Pressure Diecast System" by Yvonne Hegenbarth, Thomas Bartsch and Gerald Ristow discusses how sensor data combined with IT technology can improve production quality and help in early detection of incidents. They illustrate this for a die casting process. A flexible big data platform is presented that supports the relevant mechanism and can be applied to many other use cases as well. One central component is the anomaly detection that can be used to detect or even predict incidents.

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Dr-Ing. Harald Schöning
Software AG, Uhlandstr. 12, 64297 Darmstadt, Germany
harald.schoening@softwareag.com

Dr-Ing. Harald Schöning holds a diploma and a PhD in Computer Science from the University of Kaiserslautern, Germany. For more than twenty years, he has been working for Software AG, in various roles including developer, project lead, and chief architect, and in various areas, from databases over semantic technologies, to SOA and business process management and beyond. Today he is Vice President Research at Software AG. He is chairman of the German education initiative Software Campus, member of the board of NESSI (Networked European Software and Services Initiative), the Big Data Value Association BDVA and of the German Software Cluster. Dr. Schöning is chairman of the BITKOM working group "Industry 4.0 – Market and Strategy" and member of the steering board of the German national platform "Industry 4.0" as well as co-lead of the platform's research advisory board. He has served as expert and reviewer for the European Commission and German ministries in several contexts. He has authored and co-authored several text books and many technical papers and is inventor and co-inventor of more than 60 patents