Smart Industry: How ICT Will Change the Game!

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Around the world, industries and companies in all fields are facing a new revolution: integrating new and mostly Internet-based information and communication technology (ICT) into their complete value chains. In doing so, they hope to enable better, personalized products and services, and to improve efficient, adaptive, and flexible production, provisioning, and supply-chain processes. This revolution, made possible through the development of the Internet and the industrial Internet of Things (IIoT), is often referred to as smart industry or Industry 4.0.[1–6] Beyond integrating products with ICT (as is the case with "classical" embedded systems), it involves connecting products to each other (as is the case with cyber-physical systems) and to central service facilities. Next to that, a cloud of services (potentially from a third party) might develop around these products. These services help in using and servicing the products or their owners, along with help in providing a better user experience, offering so-called "mass individualization."[3] This is achieved by exploiting knowledge acquired through automated information collection — regarding usage, failures, maintenance patterns, and customer wishes, combined with third-party information (for instance, about weather or traffic conditions or price fluctuations).

As this technology proliferates, it won't be just the (physical) end products that will change; production facilities will change in a similar way. Production plants for physical products will involve more ICT, and will be connected to each other and the cloud — to achieve better quality, and to automatically and instantly adapt to, for instance, changing material conditions or customer demands. Such developments lead to a multitude of Internet- and IoT-related research questions, both theoretical and practical. Questions range from the design and analysis of (wireless) sensor nodes and networks to data acquisition and machine-learning algorithms, feedback control and optimization algorithms, and cloud-based services. Orthogonal to these stand questions related to overall system scalability, dependability, security, data integrity, and privacy — as well as questions about sustainability.

 1089-7801/17/$33.00 © 2017 IEEE

In many countries around the globe, research and innovation programs are starting that address this field, thereby addressing a wide variety of issues, including

- Internet-enabled decentralized monitoring and control algorithms that improve product and production-process performance;
- improved supply-chain management techniques, utilizing data acquired locally and globally;
- machine-learning algorithms and big data analytics to improve the efficiency of industrial processes and to support predictive maintenance;
- effective, reliable, and secure data collection and sharing;
- wireless sensor networks to monitor production processes and products;
- adaptive production techniques to address material diversity and individual customer wishes;
- cloud-based generic services that enable the transfer to smart industries;
- dependability, security, and privacy issues of the IIoT; and
- application-specific issues regarding smart grids, production and manufacturing systems, transportation systems, and civil infrastructure.

Using a wide variety of smart-enabling ICT technologies, such as the Internet, cloud computing, and embedded hardware and software, smart manufacturers are producing — or will be in the position to soon — not only their traditional products in a more efficient way (with fewer resources, quicker, better, and cheaper), but will also be capable of producing new types of products and services, with embedded intelligence that's always connected. They might even change their business model completely with the sheer capability of being able to monitor how a product is used by a customer, and hence, have the customer pay for use instead of having the customer own the product. Existing examples include electronic toothbrushes that monitor tooth-brushing behavior and that connect to a cloud-based database of a dentist, so as to give better feedback to both the dentist and patient, or the selling of "power-by-the-hour" by a major UK-based aircraft engine manufacturer to their end customers (airlines), rather than selling engines to the aircraft manufacturer or the airline. Moreover, they can better plan their maintenance and repair activities by continuously monitoring their engines.

In This Issue

With these advances in mind, in this special issue we present four articles that can be seen as forerunners in their field, addressing important considerations in Internet-related research and innovation for smart industry. Each article addresses many of the points raised.

The first article, "Industrial Wireless Monitoring with Energy-Harvesting Devices," by Kallol Das and colleagues addresses the use of wirelessly monitoring fatigue in industrial systems, using sensors that obtain their energy out of their environment, here from vibration. They show that through a smart combination and use of wireless sensor technology, energy-efficient monitoring solutions can be built that completely rely on harvested energy, thus avoiding the use of batteries (with all their disadvantages). Application in manufacturing and preventive railroad maintenance are reported.

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Next, "Internet of Perishable Logistics," by Krishna Kant and Amitangshu Pal proposes a new architecture for smart logistics for perishable foods, inspired by ideas developed for the Internet as we know it. They propose a layered logistics architecture that enables better truck utilization (for example, the percentage of mileage driven with a load) and potentially faster product delivery, thereby taking into account the special role that resources (trucks, trailers, and drivers), regulations, and trade unions play in what is or isn't possible practically. Using wireless sensors that measure all sorts of product quality parameters, further optimizations can be achieved. Also, their list of topics from logistics that are potentially beneficial to networking research, and the other way around, is of great interest for future research directions.

Third, "Autonomic Mediation Middleware for Smart Manufacturing," by Philippe Lalanda and colleagues focuses on a middleware platform called Cilia that enables the efficient sharing of data across large manufacturing and production plants. Cilia provides distributed control and monitoring under, depending on the application field, more or less stringent performance and/or real-time requirements. The platform lets engineers from different fields share data more easily, and also supports the sharing between heterogeneous clients.

The final article, "IIoTEED: An Enhanced, Trusted Execution Environment for Industrial IoT Edge Devices," by Sandro Pinto and colleagues addresses the important aspects of system security. Now that billions of devices are being connected, their trustworthiness is becoming of key importance. The authors propose a new security framework, especially tailored toward ARM processors, because these are used massively in industrial applications.

In looking at these innovations on the whole, what we're witnessing is an enormous explosion of Internet-enabled devices for all sorts of applications, especially in industrial settings. Industry and business will never be the same again, and ICT is the disruptive game changer.

This special issue displays a number of exemplary cases of the use of advanced ICT in the context of smart industry. These articles are forerunners in their field; at the same time, they're also just the first steps in this new and challenging field that's inventing itself as we speak. We do foresee great developments in this field, but what they will be, exactly, is difficult to say. For sure, somewhere in a garage or shed, today's youth are developing ideas that we never could have thought of and that will, once again, change our view on the future of ICT in smart industry. We eagerly anticipate the dreams and solutions that they bring to reality.

For now, we feel positive about the progress showcased in this issue, and we thank all of the authors for their submissions. We also thank the reviewers for their valuable time and comments, which made this special issue possible.

References

1. "Smart Industry," *Smart Industry: Dutch Industry Fit for the Future*, 2016; www.smartindustry.nl/en/.
2. Germany Trade & Invest (GTAI), *Industrie 4.0: Smart Manufacturing for the Future*, GTAI, 2016, http://industrie4.0.gtai.de/INDUSTRIE40/Navigation/EN/industrie-4-0.html.
3. M.E. Porter and J.E. Heppelmann, "How Smart, Connected Products Are Transforming Competition," *Harvard Business Rev.*, Nov. 2014.
4. The Industrial Internet Consortium, 2016; www.iiconsortium.org.
5. Platform Industry 4.0, Federal Ministry for Economic Affairs and Energy; http://www.plattform-i40.de.
6. M. Chui, M. Löffler, and R. Roberts, "The Internet of Things," *The McKinsey Quarterly*, Mar. 2010; www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

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