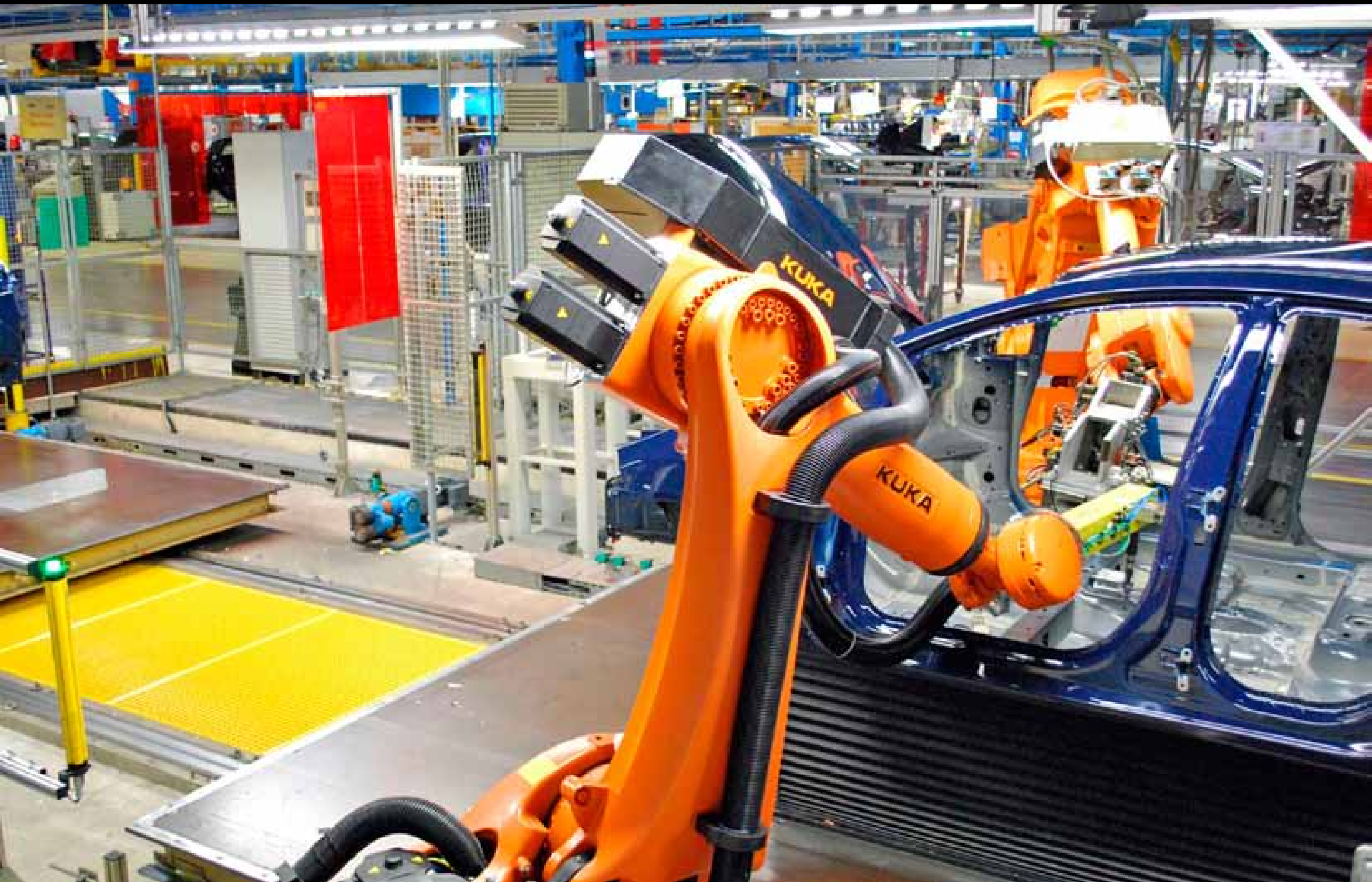
Sensor intelligence enabling Industry 4.0



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Perhaps the most hyped concept in industry today is the Industrial Internet, or Industry 4.0 — and it seems that it is impossible to escape reading these terms in the industry press and the marketing of industry technology vendors. Like it or not, this industrial revolution is already underway — driven by the need for more efficient and cost-effective manufacturing.

Predicting the convergence of industrial systems with the power of advanced computing, analytics, low-cost sensing and new levels of connectivity permitted by the internet, Industry 4.0 promises to be the next great step in industrial advancement. It is expected to bring about unprecedented advancements in automation, efficiency and flexibility.

Among the technologies supporting this revolution are cloud services, big data analytics and pervasive intelligent sensing technologies that are already at hand. Smart and agile manufacturers only need to take advantage of the technologies that are already available, using them in new and creative ways. Those adventurous enough to take these steps early will reap the rewards of improved cost-effectiveness, greater competitiveness and enhanced customer relationships. Those that don't may well be left behind, struggling to keep up.

Glenn Johnson

Editor - *What's New in Process Technology*

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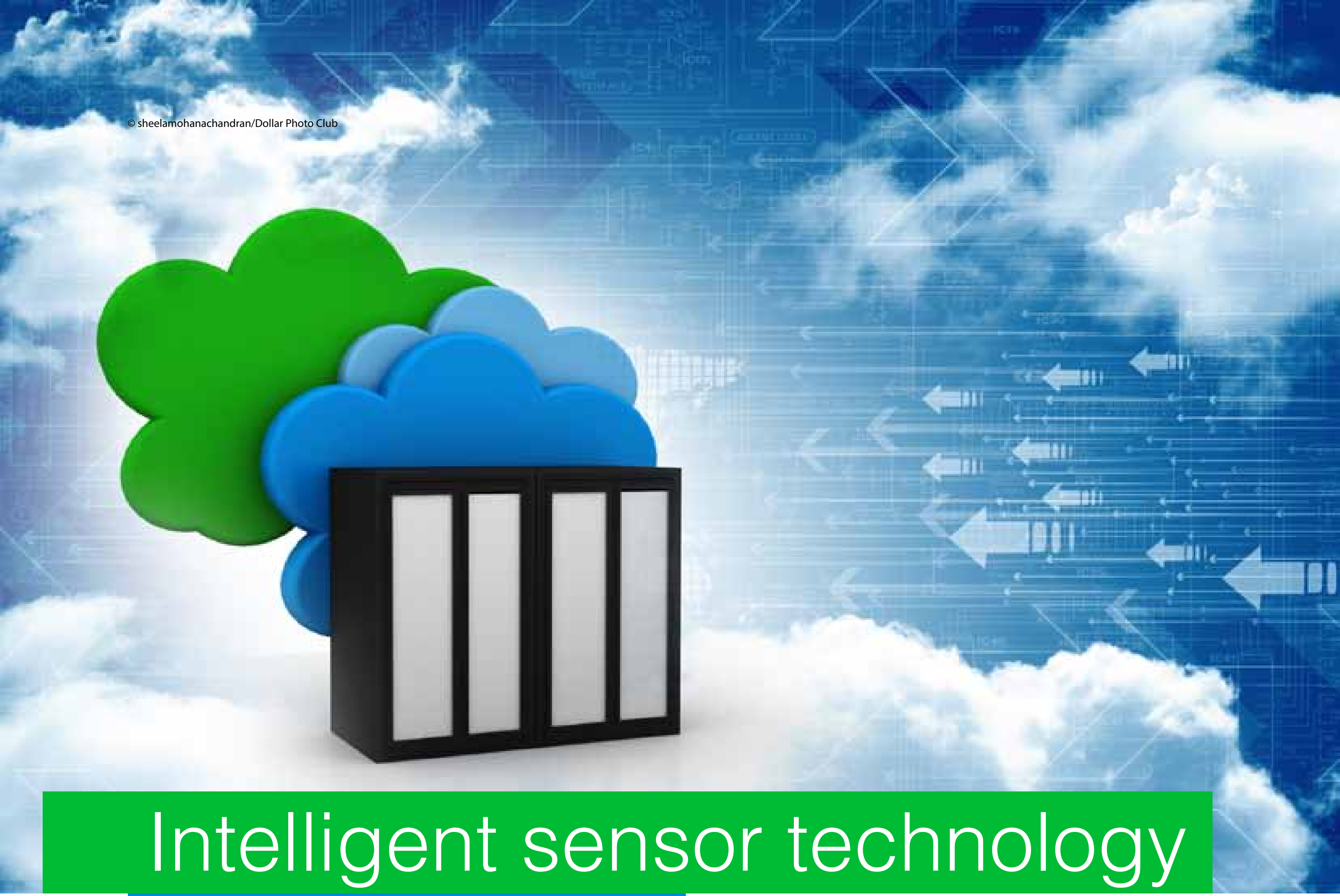

Intelligent sensor technology and the cloud

Glenn Johnson

Big data analytics will play an important role in the realisation of Industry 4.0, and the most efficient way to achieve it will be by the effective use of cloud computing technologies. Smart sensor technologies will therefore also play a leading role in ensuring the efficiency and accuracy of the source data.

Today we are constantly reading and hearing that the future of industrial production will be in the form of the Industrial Internet, Industry 4.0 or cyber-physical systems. The opportunity to use larger quantities of data to produce and supply goods in a more efficient and flexible way, while also saving resources and achieving better quality, ultimately depends on the reliability of the data input for the process chain — and the sensors that record real-time situations and convert these into useful data.

Of course, the management and usage of the data collected from sensors is the other large element of Industry 4.0 that needs to be considered. According to Dr Michael Gerstlauer of Teradata, we are entering "an era where sensor technology and the interconnectivity of machines — the Internet of Things — is driving the industry forward. This is an evolutionary journey of analytics capabilities that begins with today's Agile Data Warehouse and culminates in a future state where you have a Sentient Enterprise and manufacturing processes at optimal capacity. Industry 4.0 promises new levels of process efficiency, 'zero unplanned downtime' of machinery, and the ability to manufacture 'batch size 1' — highly customised products produced at reasonable cost to the consumer."[1]

Batch size 1

Perhaps the 'holy grail' of Industry 4.0 is the concept of a single unit batch. Smart sensor technology, coupled with adaptive automation systems, will be key to achieving this goal, in which manufacturing plants are flexible enough to adapt to individual customer requirements. Enabling high product variance in ever-smaller quantities, intelligent components (smart sensors) must be able to adapt and control themselves.

An example of a step in this direction in packaging is that it will be possible to pack items of differing sizes (such as different sized beverage bottles) on one system using smart sensor detection with automatic format adjustment. The sensors detect the change in product and signal the control system to reset itself so that the right box can be set up, the bottles can be placed inside and the box can be labelled accordingly. The system continues running automatically and does not require line shutdowns to change batches.

Smart sensor solutions, in which state-of-the-art sensor technologies are used in conjunction with integration at the control level, will provide decentralisation of certain automation functions directly in the sensor, relieving pressure on the control system and increasing machine productivity.

Perhaps the most common exemplar of the aim for batch size 1 production is an automotive production line. The sensor technology detects which assembly steps must be taken on the basis of the car body itself — thus ensuring unique identification — and guarantees continuous transparency right through to delivery. Processing steps on the object are updated via rewritable RFID transponders. RFID data cards are attached to components or integrated unseen within them. In these ways, individual vehicles can be customised 'on the fly' to meet a customer's specification.

Track-and-trace transparency

The application of smart sensor technologies such as RFID, as described above, provides other benefits.

The traceability of products during complex manufacturing and logistics processes is another area of great advancement. A transparent material flow is required in production and logistics so that production decisions can be made more quickly — such as supply of parts and raw materials.

At the delivery stage, the completed product — customised for a customer — can then be identified automatically for delivery, allowing transparency and traceability monitoring right through to the customer. Future identified faults or production flaws can be traced back to individual components or production processes at a single point in time for root cause analysis, improved quality control and enhanced customer service.

Data and the cloud

Much has been said about the explosion of data that Industry 4.0 and the Internet of Things (IoT) will produce. Cloud technologies hold the promise of making the data more accessible from multiple locations, and centralising analytics.

In reality, the quantity of data generated by any given production process will depend on the nature of the process itself. In the examples above, a single car with all its RFID-identified parts may imply hundreds of data points per product, while for the bottle packaging example, there may be only one data element per product, or a few per batch.

Depending on how the data is to be used, the data may be stored and used locally, or stored and processed by a cloud service. In the case of cloud applications, local consolidation of data at the source can improve data efficiency. For example, if a particular sensor output changes only slowly or rarely, only changes need to be stored, so local consolidation comes into play. When large amounts of data are involved, local consolidation and compression can enhance efficiency significantly.

Smart sensors that incorporate their own smart logic can reduce the data demand by providing only necessary information as desired. In the bottle packaging example, the smart sensors also assist in automatically reconfiguring the process, keeping the running production data within the packaging line for best efficiency. Only final production data should need to be forwarded on for batch track-and-trace.

The cloud and intralogistics

One application where the convergence of smart sensor data and the cloud comes into its own is in the field of intralogistics. By now we all will have experienced the simple example of parcel tracking, in which we receive emails providing access to data by which we can trace the delivery of products we have purchased online. At each step of the delivery we can see where the package is, via our computers, tablets or smartphones.

In today's intralogistics, goods are transported with a high degree of variance in content, size and weight, and at various points are weighed and measured, while having their location detected. Sensor technology identifies the goods with machine vision systems and laser-based code readers, while the volume is determined with laser scanners, light grids and encoders. Data relating to the items is scanned and uploaded to services in the cloud so that the items can be identified and compared. For example: is the parcel damaged? Is the code complete? Are the weight and volume correct? Is there a jam or has a parcel been lost?

Any defects can be tracked from all sites and any trouble spot can be identified. In addition, quality defects in the process can be identified and resolved. As the speeds on conveyors are further increased, maximum productivity is guaranteed — not just within one site, but potentially all over the world.

Smart sensor technology in this context is used to ensure high performance levels for sorting and transportation. As well as the object data, additional performance data relating to the status of the sensors, the speed of conveyors or the quality of the labels is constantly being generated.

The presentation of data at a local level can be condensed at system or factory level if necessary before being transferred to the cloud. The data delivered to the cloud by the sensors can be evaluated according to different user criteria. As described above, apps can be developed which allow the end customers to track the individual goods during the transport process on their smartphones. But it is also possible that alarm workflows can be triggered in the event of performance problems or faults, and that changes in the status of the goods will be detected in the logistics chain.

Big data that is reliable

Reliable and unambiguous identification of goods in the production process and supply chain is a vital prerequisite for efficient, autonomous control. Whether it's a single product on a conveyor or data about millions of parcels that are transported every day, the status of all recorded data must be easy to retrieve and analyse. This is where the cloud comes into play, allowing data to be collected from multiple locations, analysed and further read and shared from still other locations.

While this data offers great opportunities, the process of preparing it in a way that allows companies to make the right decisions presents a significant challenge. This seamless flow of data and information from the sensor to the control and back again is the cornerstone of Industry 4.0.

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How smart is your factory?

Managing the extreme complexity of real-time process control is one of the biggest challenges facing manufacturers today.

Ubisense surveyed 252 manufacturing engineers, product designers and quality management professionals in its 2014 Smart Manufacturing Technologies Survey and uncovered some surprising results.

The survey revealed that lack of visibility into manufacturing processes is the most prevalent issue plaguing manufacturers today. It seems that 40% of manufacturers have no visibility into the real-time status of their manufacturing processes.

Visibility is crucial for process improvement and control, but its value is far more fundamental. According to responses from the survey, nearly 10% of factories spend half their day simply looking for equipment and products. This non-value-added time can result in significant wastage. For example, a few minutes spent finding each vehicle in a heavy vehicle plant can accumulate to several hundred thousand dollars in lost inventory costs annually.

Industry 4.0, also known as the Internet of Things (IoT), introduces cyber-physical systems in which machines communicate with each other and their users, digitally and in real time, and factory processes become visible and controllable in virtual space.

In this revolution, legions of networked sensors connect to intelligent data analytics in the cloud to create cyber-physical systems capable of sophisticated real-time decision-making. Supply chains can automatically adjust based on changes in demand or production capacity, and products can communicate to machines about how they should be processed.

The manufacturing world may be talking about Industry 4.0, but Ubisense's survey shows that most manufacturers are far from embracing the cyber-physical systems which define the 4th Industrial Revolution. In fact, most factories have yet to embrace Industry 3.0, the automation age.

Eighty per cent of survey respondents said they rely on team observations to support process improvement initiatives. This means the majority of manufacturers rely on subjective, rather than objective, data when making changes to their manufacturing processes.

In fact, only 16% of respondents indicated that they rely on sensors that measure process flow and provide objective data. This lack of data may be a contributing factor in the challenge to optimise production. The lack of flow optimisation is evident when 54% of respondents reported that up to 10% of cycle time per product is non-value-added process waste.

Furthermore, in operations where products may run through a repair or rework process, the survey revealed that almost 15% of manufacturers don't prioritise product repairs at all. The repair process is one which typically receives far less technology investment than the primary manufacturing process but can be a source of significant waste.

Manufacturers need to focus on automating their systems and gaining a more valuable, objective level of visibility so they can better optimise their workflow and reduce errors in their processes.

Additional survey findings

- While 40% have no visibility into the real-time status of their company's manufacturing process, 30% of manufacturers do have access to instant, real-time status of every product.
- 56% of manufacturers are using the limited visibility data they have to identify problems as they occur, meaning that over half of respondents only know about crises after they happen.
- 40% of manufacturers are leveraging their visibility data to try to identify problems before they occur. In these situations, frontline managers can be much more proactive by identifying a pending stoppage and making adjustments in advance to maintain flow.

Ubisense operates in the vehicle and industrial manufacturing arena where its 'Smart Factory' uses real-time location data and other owned data from manufacturing and enterprise systems to give manufacturers process visibility. However, the survey does give the impression that the smart factory may still be a way off in the future for a variety of industries, and that there is still a lot of automation possible in the interim.

Industry 4.0: A new era

Martin Krueger, Rainer Drath, Heiko Koziolek, Zied Ouertani, ABB Corporate Research

A new era of industrial innovation is upon us. Referred to as the fourth industrial revolution, the deeper meshing of the digital world with the world of machines holds the potential to bring about a profound transformation of industry worldwide.

The world is on the threshold of another industrial revolution - this one a result of the convergence of the global industrial system with the power of advanced computing, analytics, low-cost sensing and new levels of connectivity permitted by the internet.

The industrial revolution began when manual labour was replaced with mechanical power, starting late in the 18th century with the invention of the mechanical loom.

This revolution continued to develop in stages over the next 150 years, with further mechanisations and through the combination of steam and water power. The second stage dates to the emergence of electrification and automation. At every stage, productivity accelerated sharply beyond that stage which had preceded it.

The third, and most recent, industrial revolution stage began in 1969 with the first digital and freely programmable control systems, which replaced the traditional hardwiring of analog logic and control programs. This stage built the foundation of today's automation pyramid and modern process control systems and has continued right up to the present day. An overview of these industrial revolutions is presented in Figure 1.

The next industrial stage

The arrival of the internet in the consumer world in the 1990s brought unprecedented change to daily life: social networks, online TV and almost instant access to huge amounts of information.

A similar revolution is now expected in industry, as government and industrial consortiums around the world see a trend of increased utilisation of internet technology in industrial production systems. Devices in the production environment are increasingly being (wirelessly) connected to each other and a network - whether a private network or the internet. Eventually industrial production systems will be capable of autonomously exchanging information, triggering actions and controlling each other more independently.

The working groups developing this new concept are widely diverse, so the description of the concept, and even its name, varies. For example, the name Industry 4.0 (Industrie in German) was conceived by a German-led working group, while in the United States a similar initiative is called Industrial Internet[1,2]. Both initiatives are based on technologies associated with the Internet of Things (the ubiquitous connection of all devices to the internet) and cyber-physical systems, a combination of physical objects and software systems. The initiatives mark efforts aiming to prepare global industry for what is expected to come.

Technical drivers for Industry 4.0

A number of technical developments are driving the efforts of Industry 4.0[3] (see Figure 2). Communication infrastructure will become ubiquitous throughout industrial production facilities as it becomes cheaper and readily available. This network availability builds the basis for tasks such as data acquisition, engineering, operation, maintenance and advanced services.

Once a network is in place, more devices, machines, facilities and plants will be connected, either on the internet or on a private company network. All connected physical objects will be represented by data objects in the network. As a result, these data objects form a second virtual identity within the cyber-world, the cyber-physical objects. These objects will be easy to locate, explore and analyse and will hold information about their functionality as well as their requirements.

Devices, machines, facilities and plants will be able to store knowledge about themselves beyond the physical representation and directly at the data object in the network. Each will publish updates on their current status, history, related documentation or technical requirements in the network. Such information can then easily be updated by the device's owner, service technician or parent system.

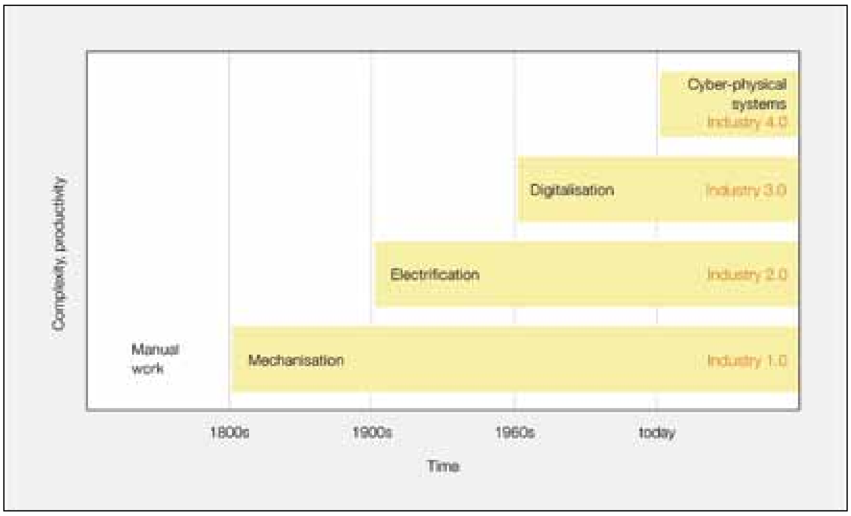

Figure 1: Industrial revolutions and enabling technologies.

As part of a cyber-physical system, intelligent algorithms and embedded software will be able to explore these new data sets to generate value-added services that would not have been feasible or economical before (Figure 3). This field is a topic of ongoing research[4], but, from today's perspective, remote or data-driven services mark the first steps toward these new services.

The increasing level of integration of cyber-physical objects in an internet-technology-enabled network will inevitably lead to higher levels of information processing. This will then open new doors for widely known concepts from the consumer market to enter the business-to-business market, such as plug-and-play (like plugging a USB mouse into a computer, with drivers being automatically downloaded from the web and always kept up to date) or plug-and-produce (such as exchanging an old device with an equivalent new one which then functions automatically, without the need for manual engineering, commissioning or servicing).

Cyber-physical systems have been present in the business-to-consumer market for some time. One application of the concept is the purchasing of fuel by consumers from German petrol stations. Fuel prices are submitted to a central data repository, where all stations are represented as data objects in the network. The value of isolated data objects alone is minimal. However, with the advances of mobile technologies and smartphone applications, millions of users can now make informed decisions for purchasing fuel by consulting the current prices at their individual locations. In this example, the architecture of the cyber-physical system breaks down in the following way: the physical object (petrol station), the cyber part (the data object with prices) and the software layer (the smartphone apps).

Industrial demands

The introduction of communication and internet technologies into industrial production has tremendous potential to increase productivity and flexibility, but it also raises concerns - in particular for plant owners, who combine investments, know-how, production capabilities and profit in their plants. Among the current visions of Industry 4.0, the value propositions still need to be identified. To create a sustainable acceptance of the next industrial revolution, some practical requirements need to be fulfilled:

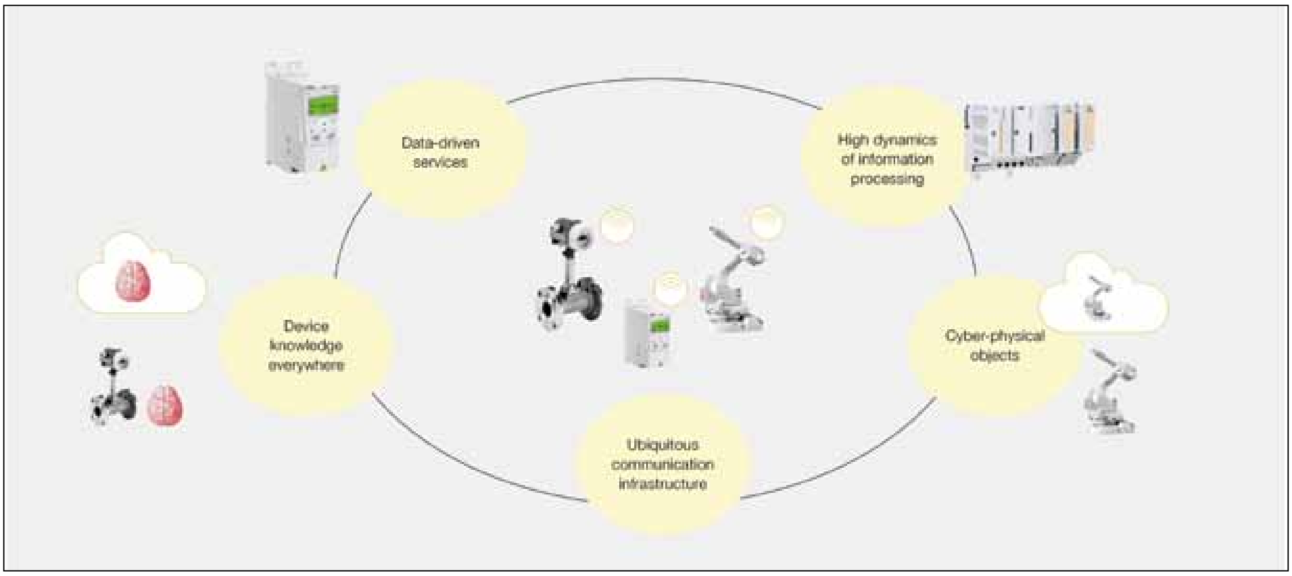

Figure 2: Technical drivers for Industry 4.0.

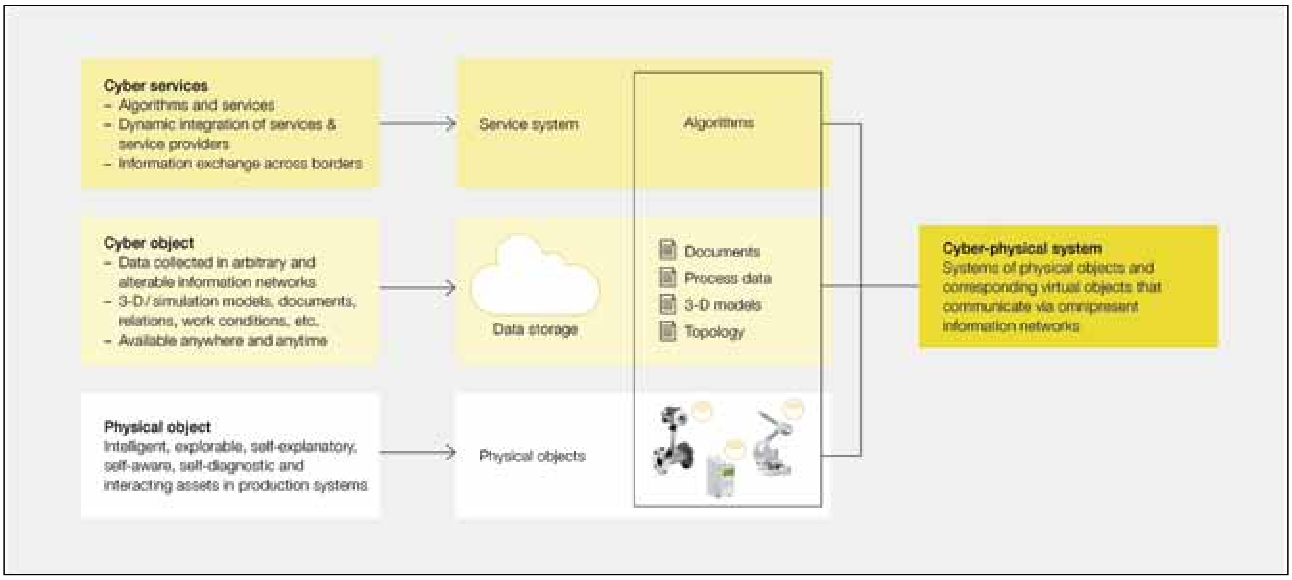

Figure 3: Cyber-physical system.

- In order to protect investments, new technology needs to be incrementally introduced into existing production facilities, making sure not to disrupt the existing machines and technology.
- To maintain stability internet technologies must not disrupt production, neither through network outages nor through intended remote access to assets.
- The access to plant-specific data must be carefully controlled by the plant operator. Write access to production-relevant assets, machines and facilities needs an additional audit to cross-check the validity of the intervention in the context of the running production.
- As always, security is a vital aspect. Unauthorised access to data and services needs to be prevented to ensure information security and to control critical aspects of the production facilities.

Furthermore, production systems in general have stronger requirements on non-functional properties - such as availability, real-time capability, reliability, robustness, life cycle, productivity and cost - compared with IT systems in other markets.

Integration topology

To facilitate the further development of Industry 4.0 an integration topology has been adopted by the German Industry 4.0 initiative[5], initially developed by ABB. The topology will allow an incremental introduction of new technology and production processes.

The core of the integration topology is the separation of the established production network from the new Industry 4.0 network (Figure 4). From the technical aspect, the separation can be implemented by either physically separated networks or logically separated networks within existing ethernet-based networks. As shown in Figure 4, the green production network symbolises an automation system that fulfils the industrial requirements on availability, reliability, sustainability and security. The yellow Industry 4.0 network enables new services and provides added value to the user. The production is not dependent on the Industry 4.0 network; therefore, failures of the network will not interrupt production.

In the first step of an implementation of the topology, assets, devices, production lines and factories are connected to the Industry 4.0 network with read-only access (yellow markers). Authenticated participants can read, for example, device IDs, diagnostic data, parameters or production data. This data will form the foundation of future Industry 4.0 value-creation processes. In a second step, write access will be introduced with an approval instance to avoid unintended effects on the running production.

The data of the yellow Industry 4.0 network is collected in a private, secure storage system. Access to this data is controlled by the data owner, ie, the plant operator. Publication of this data to the Industry 4.0 services system is controlled by interfaces and permission systems. Added value can be created - either by services within the private data system, or through third-party services within the Industry 4.0 services system.

This integration topology addresses the industrial requirements of investment protection, system stability, controllability and data security issues. The German Industry 4.0 steering committee has published this topology under the Industry 4.0 umbrella[5].

What is needed

Many components comprising the fourth industrial revolution are not new. Cloud technology, network devices, communication interfaces and data-driven services are well established in many markets. However, in order for the next stage to move forward, a number of agreements and principles need to be established, such as:

- Cross-vendor agreement of standardised syntax and semantics to identify, collect and store data;
- Cross-vendor agreement of standardised services based on standardised interfaces, communication and semantics;
- Introduction of principles such as (for example) self-exploration or plug-and-explore to facilitate cross-vendor value creation;
- Availability of services to create added value from the cross-vendor availability of data;
- Interlinking of services with other third-party services;

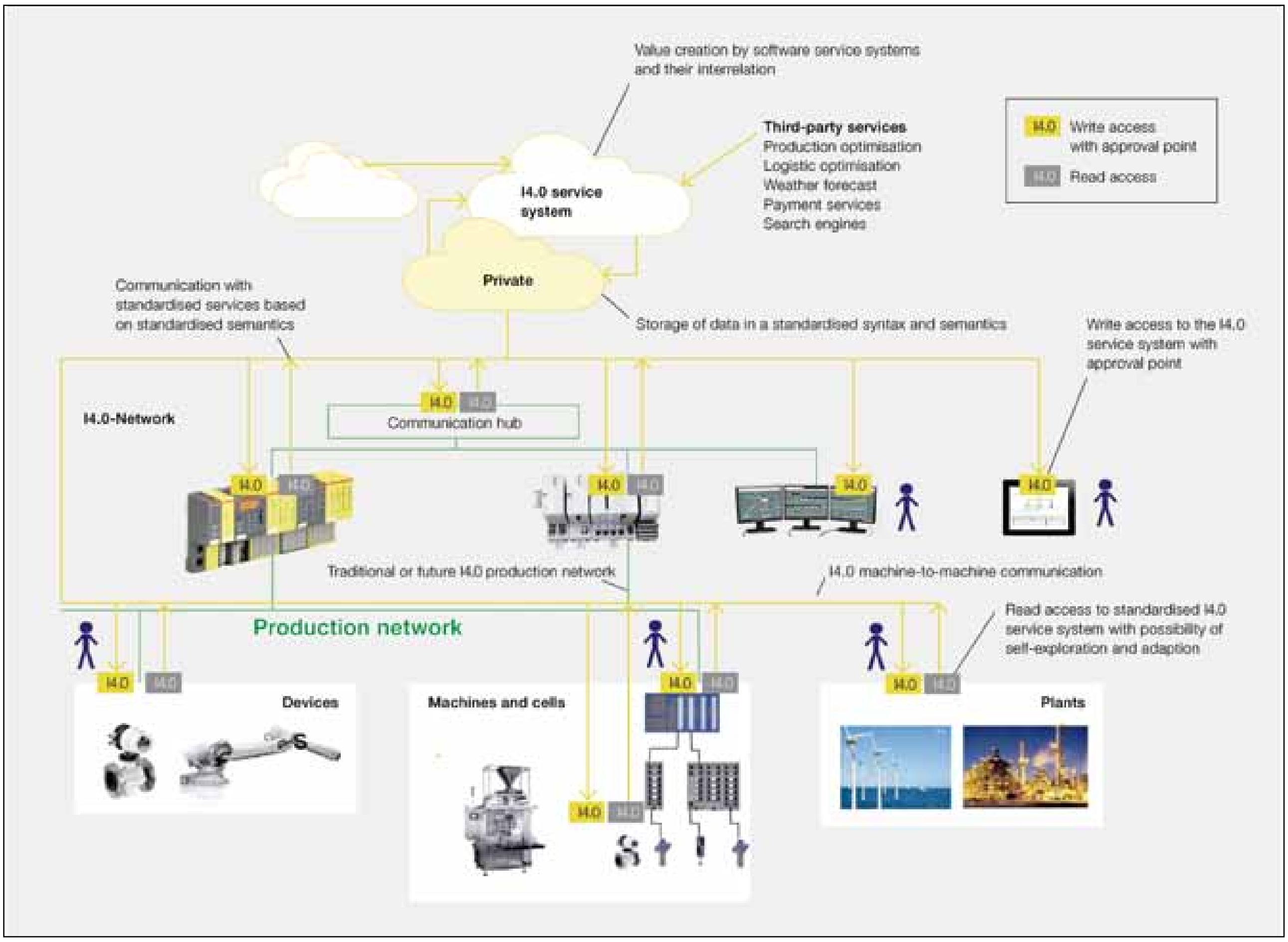

Figure 4: Integration topology for Industry 4.0.

- Availability of data throughout the value chain and supply chains in real time;
- Dynamic, partly autonomous adaptation of production services to changes in environmental parameters (such as plug-and-produce for replacement devices or update of software during continued production);
- Reorganisation of production processes to systematically exploit data and services.

This new industrial revolution is a phenomenon that will flourish. The key to bringing added value to the customer lies in better understanding the requirements for standardisation enabling the interaction of Industry 4.0 technologies. It is also important to investigate application cases in different industrial ecosystems to confirm the potential of the trend[5].

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