The Technology-Network:
Intelligent Technical Systems OstWestfalenLippe . Germany

it´s owl

On the road to Industry 4.0: Solutions from the Leading-Edge Cluster it's OWL (Intelligent Technical Systems OstWestfalenLippe)

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Leading-Edge Cluster it's OWL delivers solutions.

In the technology network it's OWL (Intelligent Technical Systems OstWestfalenLippe), global market and technology leaders in mechanical engineering, electronics and electrical engineering, along with the automotive supply industry, pool their strengths.

Together with regional research institutes, they work together on new technologies for intelligent products and production systems through 46 projects. The focus is on the fields of self-optimization, human-machine interaction, intelligent networking, energy efficiency and systems engineering.

This creates a unique technology platform, which companies can utilize to increase the reliability, resource efficiency and user-friendliness of their products and production systems.

An innovative transfer concept, which allows for 120 transfer projects over the next three years, will provide small and mid-sized companies with the chance to participate in the cutting-edge technology.

A winner of the Leading-Edge Cluster Competition conducted by the Federal Ministry of Education and Research, the flagship of the German government's high-tech strategy, it's OWL is considered throughout Germany to be one of the largest initiatives of Industry 4.0, thus making an important contribution to safeguarding production in Germany.

This brochure describes the Leading-Edge Cluster's methods and solutions within the context of Industry 4.0. The modules of the technology platform and its practical application in machines and systems are presented against the backdrop of our innovative technology concept.

We have what it takes to take the path towards the fourth industrial revolution step by step. After all, OstWestfalenLippe is one of the five most innovative regions in Germany – according to a competition held by the Federal Ministry of Economics in January 2014. ■

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Industry 4.0 – the fourth industrial revolution?

The real world and the virtual world are evolving and growing closer together.

Industrial production has been subject to change since its very beginnings. Often, this change has been so powerful that, in retrospect, the term revolution has been used to describe it, as shown in Fig. 1.

The **first industrial revolution** is the term used to describe the transformation from purely manual work to machine production, which initially impacted the cotton-spinning and weaving mills in central England from 1770. The great breakthrough came in 1782 with the steam engine invented by James Watt; this made it possible to have a supply of energy at any location and freed mankind from its dependence on the forces of nature [Geo08].

The **second industrial revolution** was characterized by intense mechanization and electrification combined with pronounced rationalization. This made considerable growth possible and ensured supply to the mass markets that emerged. The

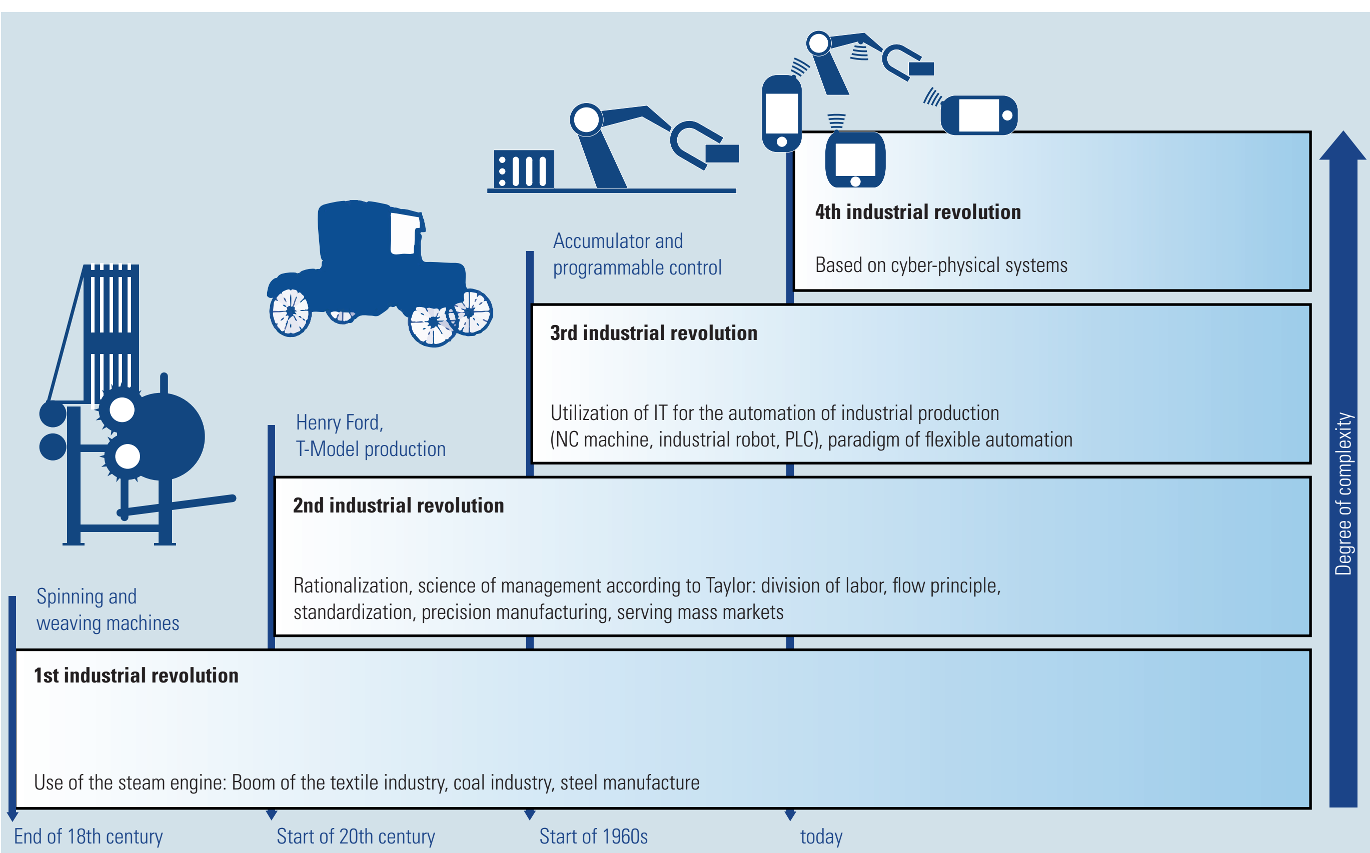

Fig. 1: Historical development of industrial production (according to the DFKI – the German Research Center for Artificial Intelligence)

most essential characteristics of rationalization, shaped by Taylor, in this era were the division of labor, standardization, precision manufacturing and assembly line work. Henry Ford applied this new methodology to the production of the T-Model and achieved pioneering success with it in automobile manufacturing. Electricity greatly stimulated the decentralization of the mechanical system.

The **third industrial revolution** was based on the development and expansion of the computer and the microprocessor. This led to numerically controlled work machines (NC machines, industrial robots), which could be modified significantly faster than conventional automated mechanical systems. The paradigm of flexible automation came into being; the corresponding systems were characterized by high productivity and flexibility.

For some time now, we have been observing the change from a national industrial society to a global information society. Information and communication technologies are growing together and pervading all areas of life. Production is understood to be a complex, information-processing system, in which the interdisciplinary and cross-company production processes of goods and services and their ongoing support by IT and communication technology play a prominent role.

In the light of this, devices and systems in our real environment that are controlled by integrated software are increasingly being integrated into the global communication network, where 'internet' is the key term. The real world and the virtual world are clearly growing closer together, which is expressed by the term cyber-physical systems.

Within the context of the industrial production, this opens up a new perspective, which is considered by many to be the **fourth industrial revolution** – Industry 4.0 [KLW11], [FA13].

The road to the new Industry 4.0 concept will be **evolutionary** and the effects on the system of industrial production will be regarded as a revolution when viewed retrospectively. In the midst of all this euphoria for Industry 4.0, it must not be overlooked that the introduction and use of IT systems is positioned at the end of a well thought-out chain of activities and not at the start; "the cart must not be put in front of the horse".

Fig. 2 is intended to convey this message clearly and plausibly: Effective IT systems require well-structured business processes. These in turn follow a business strategy, the aim of which is to achieve potential for success in the future. To that effect, if Industry 4.0 is not to suffer the same fate as computer integrated manufacturing (CIM), it is necessary to act entrepreneurially [GP14], [Jas12].

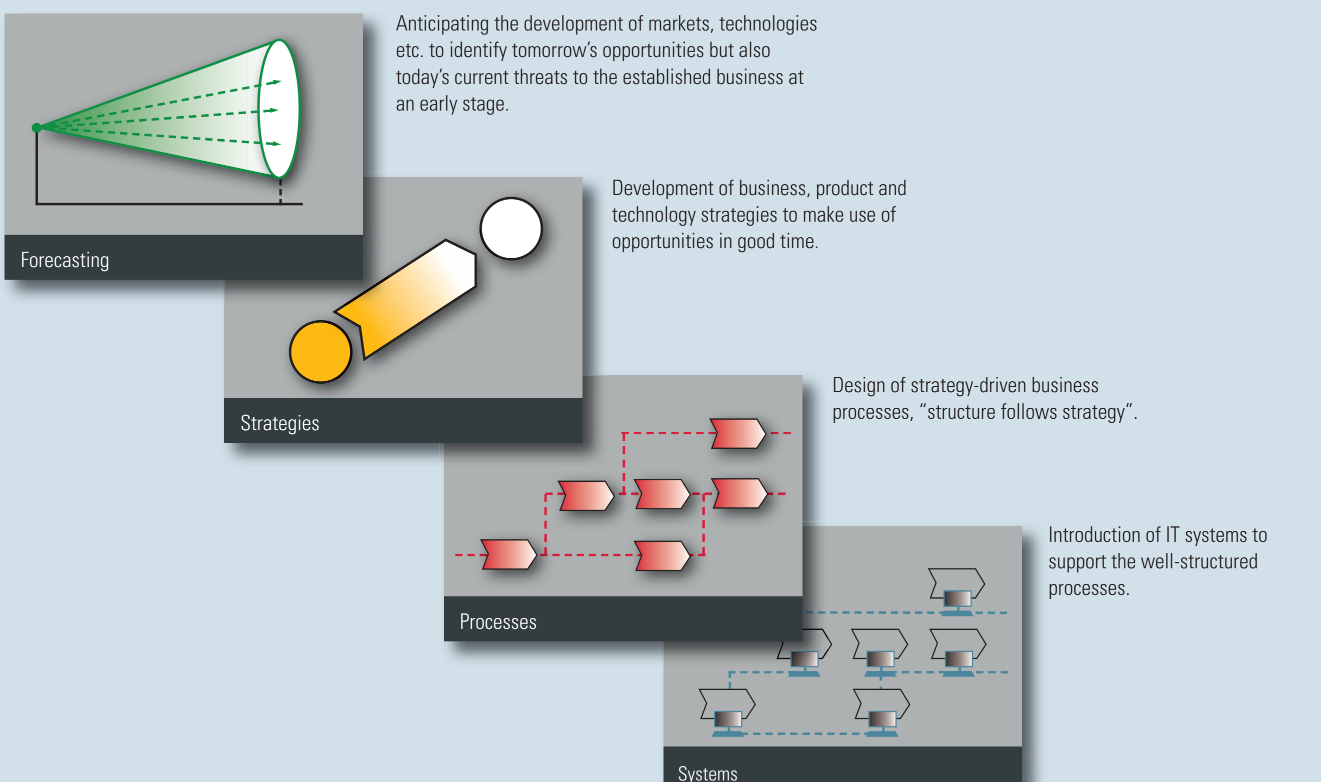

Fig. 2: 4-layer model for future-orientated company organization [GP14]

The Leading-Edge Cluster it's OWL within the context of Industry 4.0

Intelligent products and production systems through the symbiosis of informatics and engineering sciences.

The technology network "it's OWL" (short for Intelligent Technical Systems OstWestfalenLippe) is an alliance of 174 businesses, universities, research institutes and organizations working together to jointly shape the innovative leap from mechatronics to intelligent technical systems.

To this end, global market leaders in mechanical engineering and the electrical, electronics and automotive supply industries, as well as internationally renowned research institutes bundle their resources. The objective they share is to secure the OstWestfalenLippe region a leading position among global competitors in the field of intelligent technical systems. 46 applied research projects worth a total of around 100 million euros will be carried out over a period of five years to achieve this aim.

In January 2012, the joint development strategy was one of the winners of the Leading-Edge Cluster Competition run by the Federal Ministry of Education and Research (BMBF). The competition is the flagship of the German federal government's high-tech strategy. Its aim is to support high-performance and topical clusters and strengthen regional potential for innovation. The technology network it's OWL receives 40 million euros in subsidies and the right to call itself a "Leading-Edge Cluster".

The it's OWL technology concept

The technology concept describes what is to be understood by intelligent technical systems and, in particular, their properties. The realization of the four properties of **adaptive, robust, predictive** and **user-friendly** is based on the foundations of basic research carried out by the three leading universities in the areas of self-optimization, cognition, intelligent human-machine interaction and intelligent networking. From the beginning onwards, the technology concepts were aimed at the concepts of cyber-physical systems and Industry 4.0.

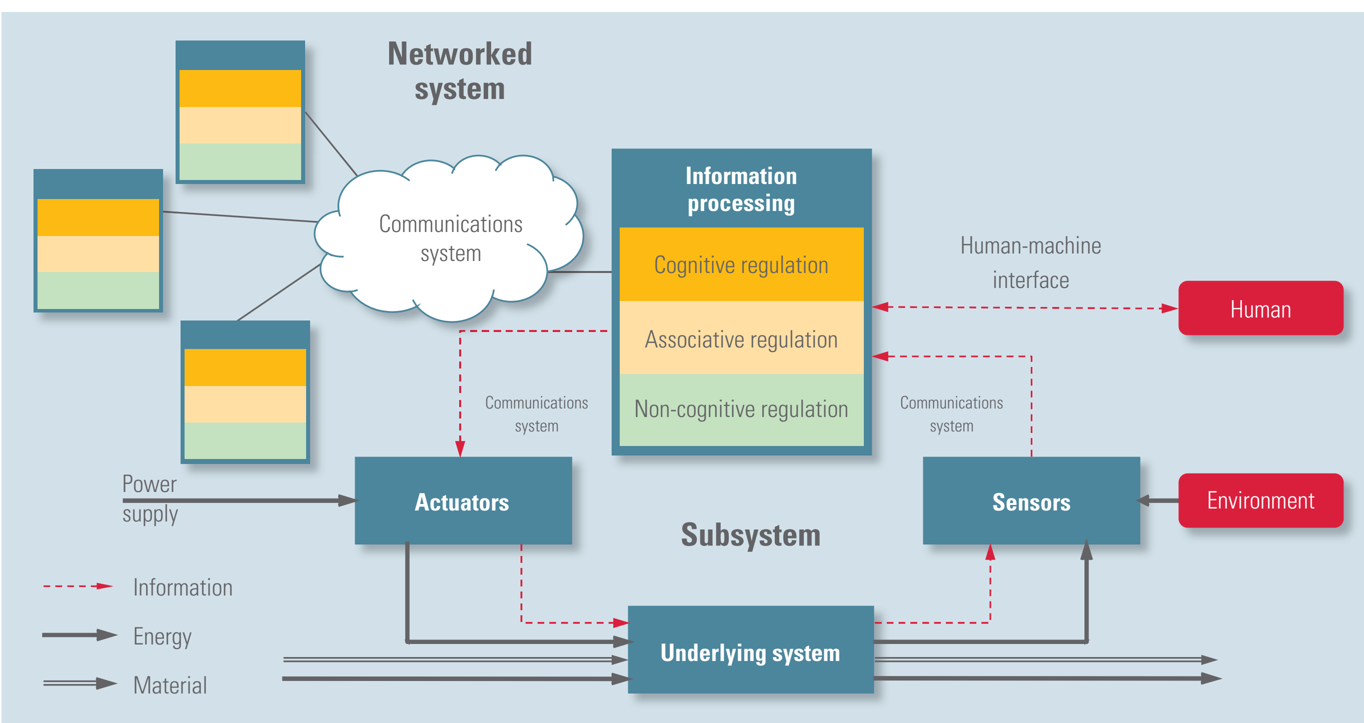

Fig. 3: Technology concept – from intelligent subsystems to a networked, cyber-physical system

In **five cross-sectional projects**, the basic principles developed at the leading universities are transformed into an implemented technology base that can be utilized by companies. These principles can be considered to be at the cutting edge of relevant developments both conceptually as well as in their practical implementation.

The technology concept of it's OWL consists of an intelligent technical system in four units: the underlying system, sensors, actuators and information processing technology (Fig. 3).

Information processing technology plays a central role here. It intervenes, via the communication system, between the sensor technology, through which the required information on the operational situation can be identified, and the actuator technology, which carries out the final physical system action together with the underlying system. Underlying systems are generally considered to be mechanical structures.

We call such an elementary configuration of the four named units a **subsystem.** Examples of subsystems are drives, automation components, intelligent energy accumulators etc. **Systems** such as machine tools are generally made up of several subsystems, which are to be considered as an integrated group [GTD13].

First and foremost, the type of information processing characterizes the intended change from mechatronic to intelligent technical systems. Thus the former only has a reactive and rigid connection between the sensor and actuator technology. Conversely, intelligent technical systems are able to specifically modify these. However reactive action flows will not be completely replaced as the majority of existing system mechanisms have to run in a way that is reactive and reflexive for safety reasons.

The **three-layer model** for behavior management originating from cognitive science [Str98] (Fig. 3) illustrates this abstract viewpoint of the information processing intelligent systems:

The non-cognitive regulation contains the continuous control and regulation (motorized regulating circuit) as well as reflexes. Transferred to a mechatronic system, an example would be ensuring the controlled physical motion of a multi-body system, e.g. active chassis of a car.

The associated regulation includes, among other things, the stimulus-response mechanisms and conditioning. In a technical system, the controller switchover – e.g. from a speed regulator to an interval control system – would be reliant on this layer.

The cognitive regulation displays typical functions of artificial intelligence such as goal management, planning and behavior control. One form of technical implementation at this level would be self-optimization, whereby the system automatically modifies the goal to meet changing operating conditions and then autonomously adjusts its behavior to the changed goal. [GRS14].

A further central point of the technology concept is for intelligent technical systems – which are often geographically distributed – to communicate and cooperate. The functionality of the **networked system** created in this way is only developed through the interplay of the individual systems. Neither networking nor the role of the individual systems is static; on the contrary, both have the ability to change according to the required overall functionality.

Networking is being increasingly implemented at global dimensions. In the process, methods, such as the cyber-physical system, that in the past were considered to be completely separate, are integrated, for example cloud computing on the one hand and integrated systems on the other. The networked system is no longer able to be controlled solely by global control, but rather global good behavior must also be achieved by local strategies. [GTD13].

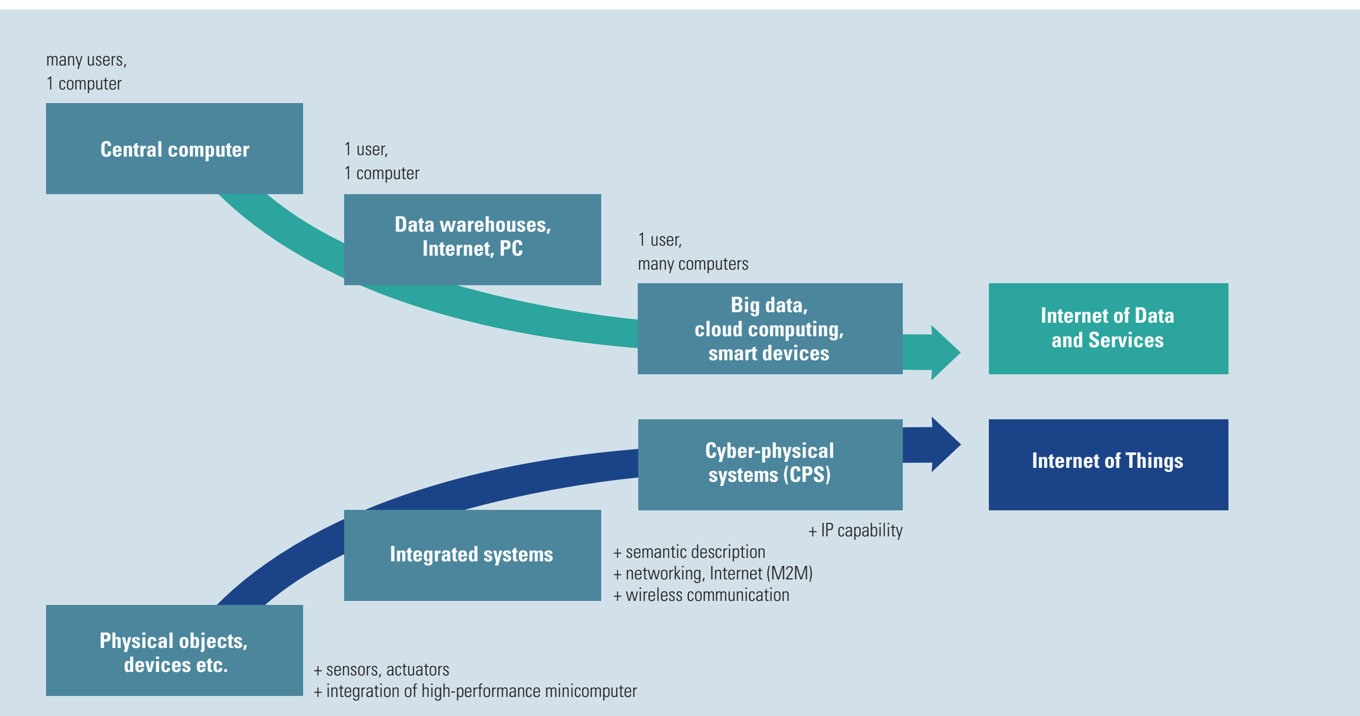

Fig. 4: Two converging development strands as innovation driver (according to Forschungsunion 2013)

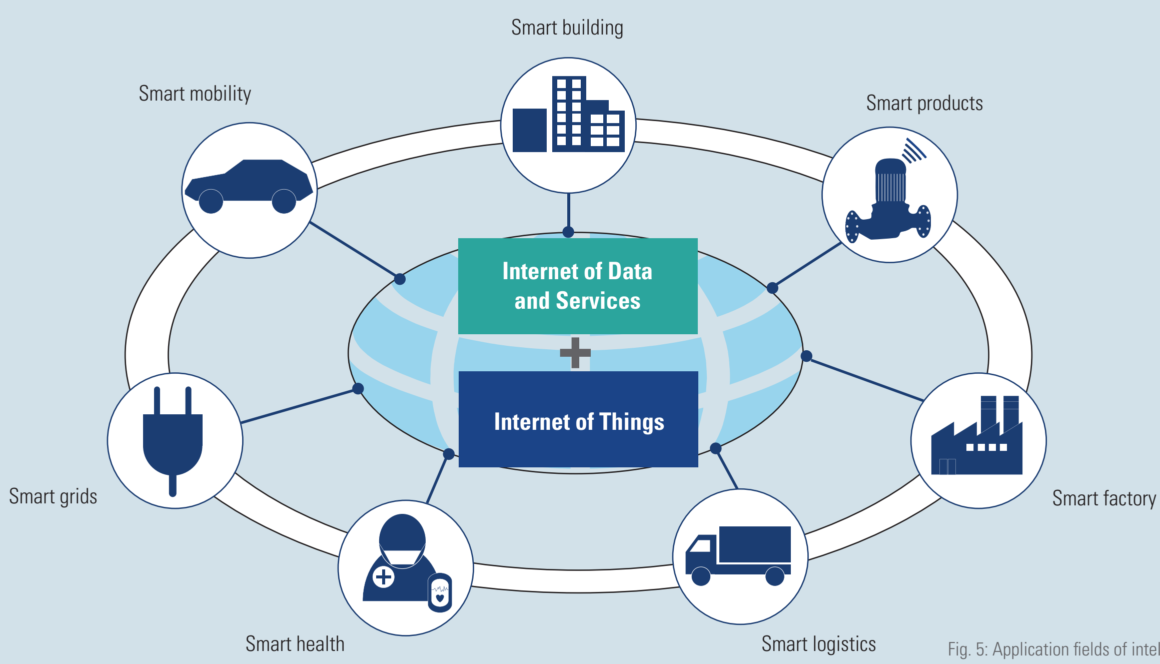

Fig. 5: Application fields of intelligent networked systems (according to Forschungsunion 2012)

Innovation driver Internet of Things and Internet of Data and Services

As presented in Fig. 4 (see page 7) there are two converging development strands, which will open up new perspectives in many areas of life and the economy. These new fields of application are represented as examples in Fig. 5.

The **Internet of Things** is ultimately the result of the technology concepts described above. Here physical intelligent objects, e.g. workpieces, machines, operating resources, warehouse and transport systems and production control centers communicate via the Internet or other networks.

On the other hand, the change to a virtual business world is based on an increasing number of offers of Internet-based services and the availability of large volumes of data, which can be processed ever faster.

Global data networks, based on technologies such as big data, cloud computing and smart devices are what make the **Internet of Data and Services** a possibility; out of which arise fascinating opportunities for innovative services, often cleverly combined with benefits in kind, and attractive business models [ASSW14].

The **33 innovation projects** from the Leading-Edge Cluster can be seen in the light of this development, which leads to innovative market services. ■

Smart products	Smart factory	Smart logistics[1]
Environment detection system CLAAS	**Production islands** HARTING	**Energy-efficient intralogistics** Lenze
eXtreme fast control Beckhoff	**Intelligent power controllers** AEG	**Intelligent networking of agricultural machinery** CLAAS
Highly integrated electronic motor Lenze	**Intelligent processing of large parts** Goldbeck	
Innovative automation devices Weidmüller	**Intelligent machine tools** DMG MORI SEIKI	
Integrated control engineering KEB	**Interactive robotics in the production process** HARTING	
Intelligent system modules Wittenstein	**Scientific automation** Beckhoff	
Intelligent hazardous material storage areas DENIOS	**Self-optimizing laundry** Kannegiesser	
Self-optimizing bonder Hesse	**Self-X-production processes** Weidmüller, Hettich	
Self-optimizing mixer WP Kemper	**Virtual production planning** DMG MORI SEIKI	
Separator i4.0 GEA	**Versatile production technique** Phoenix Contact	
Software defined industrial ethernet WAGO		

[1] Numerous applications in the area of logistics and within the context of Industry 4.0 are being developed by the LogistikRuhr efficiency cluster, also awarded the title of Leading-Edge Cluster. A strategic and professional cooperation exists between the two Leading-Edge Clusters.

Table 1: it's OWL innovation projects (selection) within the context of Industry 4.0 (Photo: Lenze, CLAAS)

Technology platform for intelligent technical systems

Five cross-sectional projects make the results of the leading-edge research usable for companies.

The constructive management of 46 research projects with a total volume of approx. 100 million euros requires adequate project organization.

The project organization of the cluster as seen in Fig. 6 displays 33 innovation projects, five cross-sectional projects and eight sustainability initiatives.

Innovation projects and cross-sectional projects result in matrix organization: The innovation projects driven by the industry make use of the technology platform provided by the universities within the framework of the cross-sectional projects.

The sustainability initiatives promote the development of skills in all 140 cluster businesses and consolidate the development dynamic of the clusters extending beyond the end of the financial support. ■

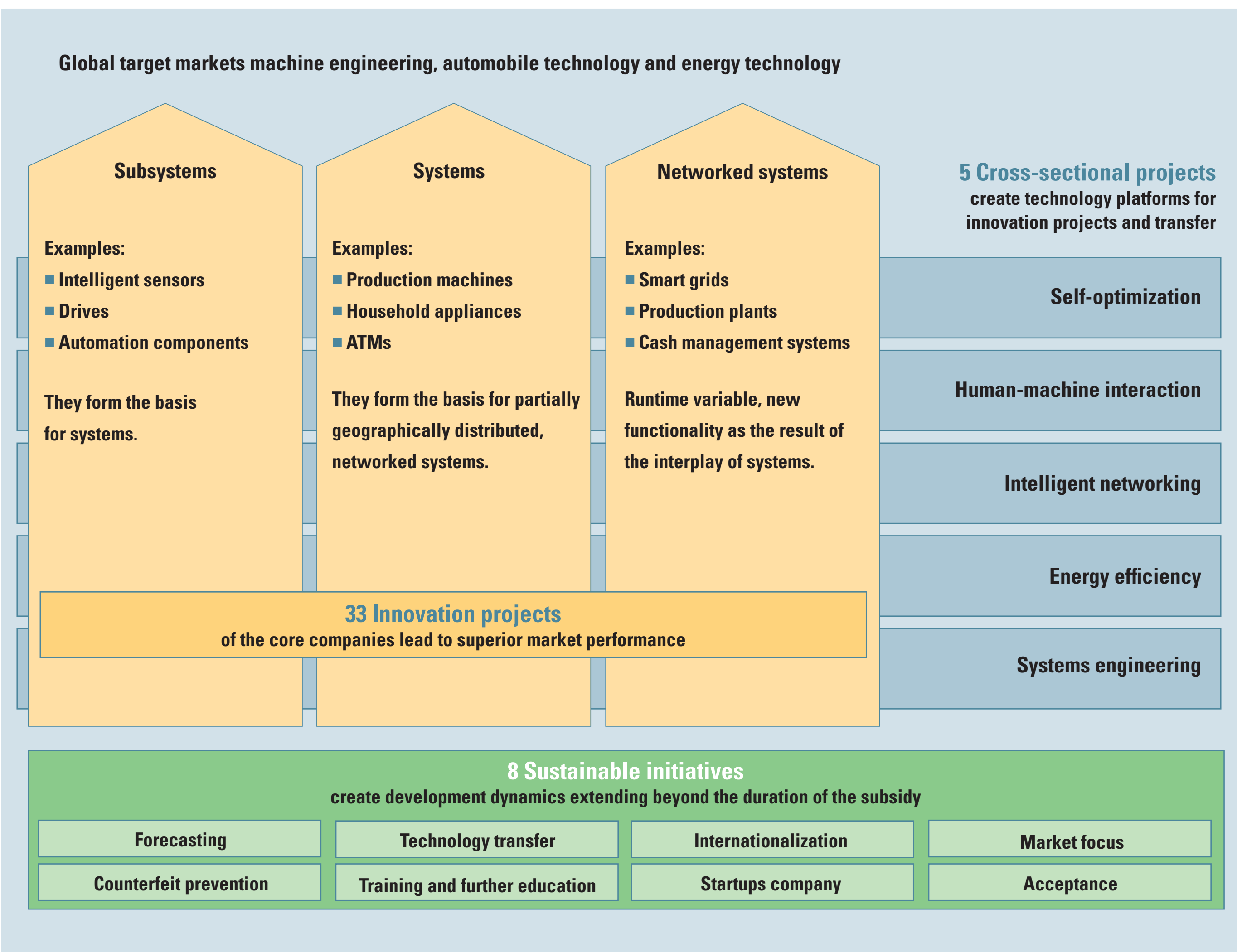

Fig. 6: Leading-Edge Cluster project structure

The **matrix organization** (innovation projects/ cross-sectional projects) has more than exceeded high expectations:

- The innovation projects utilize technological synergies; the wheel is not reinvented each time.
- The technology base is enriched by the accomplishments of the cross-sectional projects and their exacting requirements.
- Access to the technology base remains open to the companies in the cluster and, if required, also for others outside the cluster. This makes it possible for a large number of companies, in particular small and medium-sized ones, to participate in the cutting-edge technology. The aim is the practical implementation of the 120 planned transfer projects.

Below, we will examine the **five cross-sectional projects** that form the technology platform of the cluster. Fig. 8 shows the way in which the cross-sectional projects are classified in the technology concept.

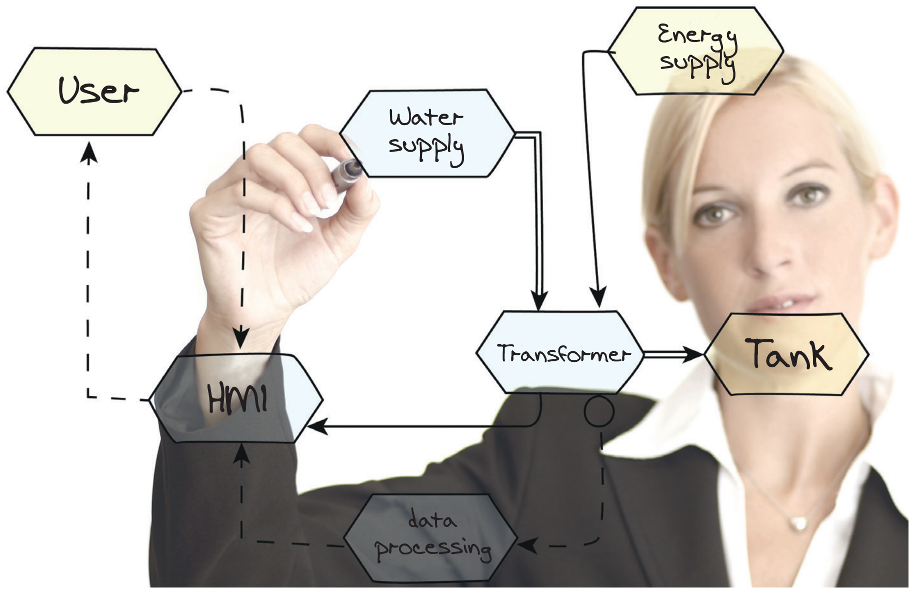

Fig. 7: Systems engineering forms the framework of the technology platform (Fraunhofer IPT)

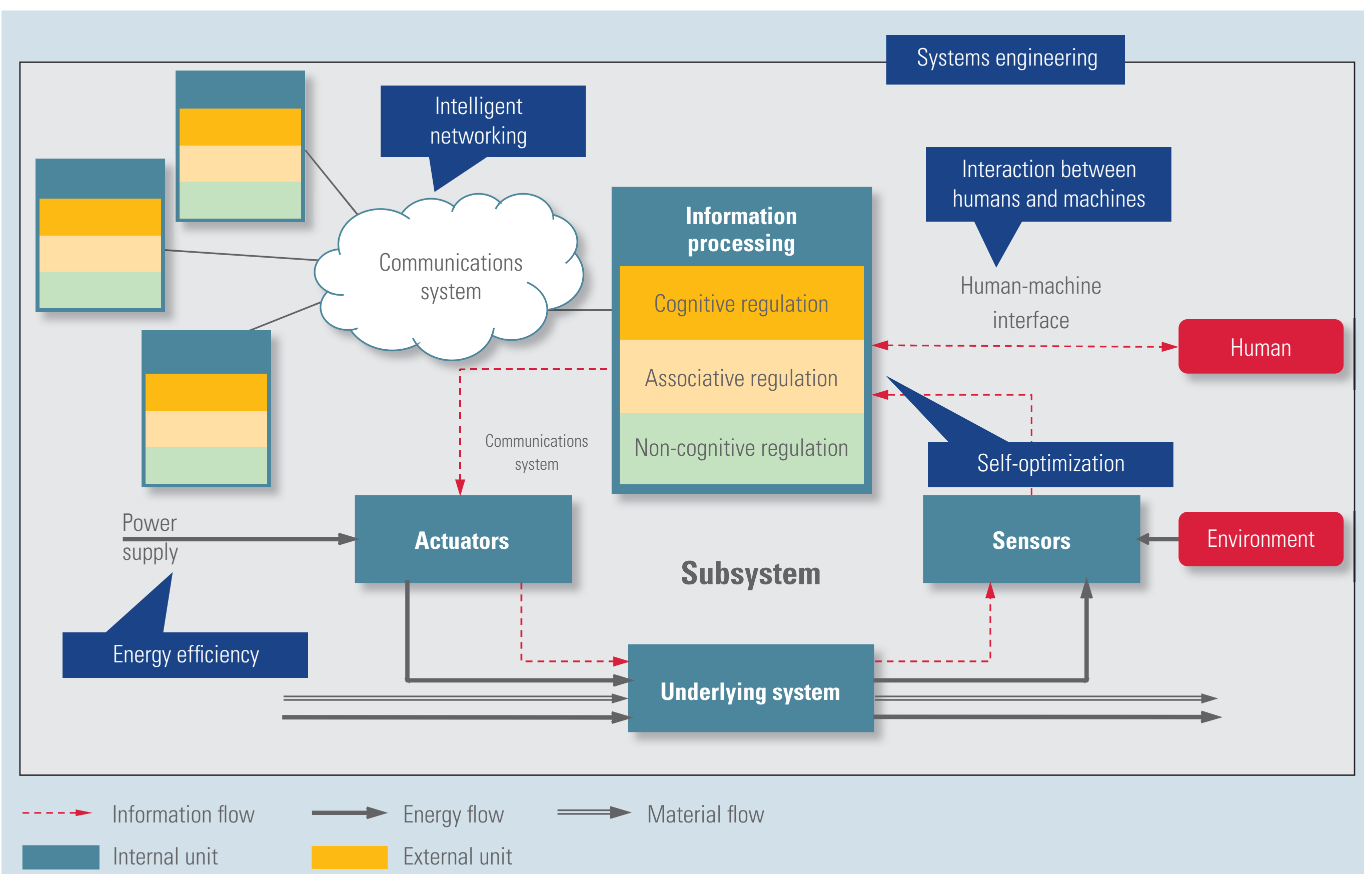

Fig. 8: The five cross-sectional projects in the technology concept

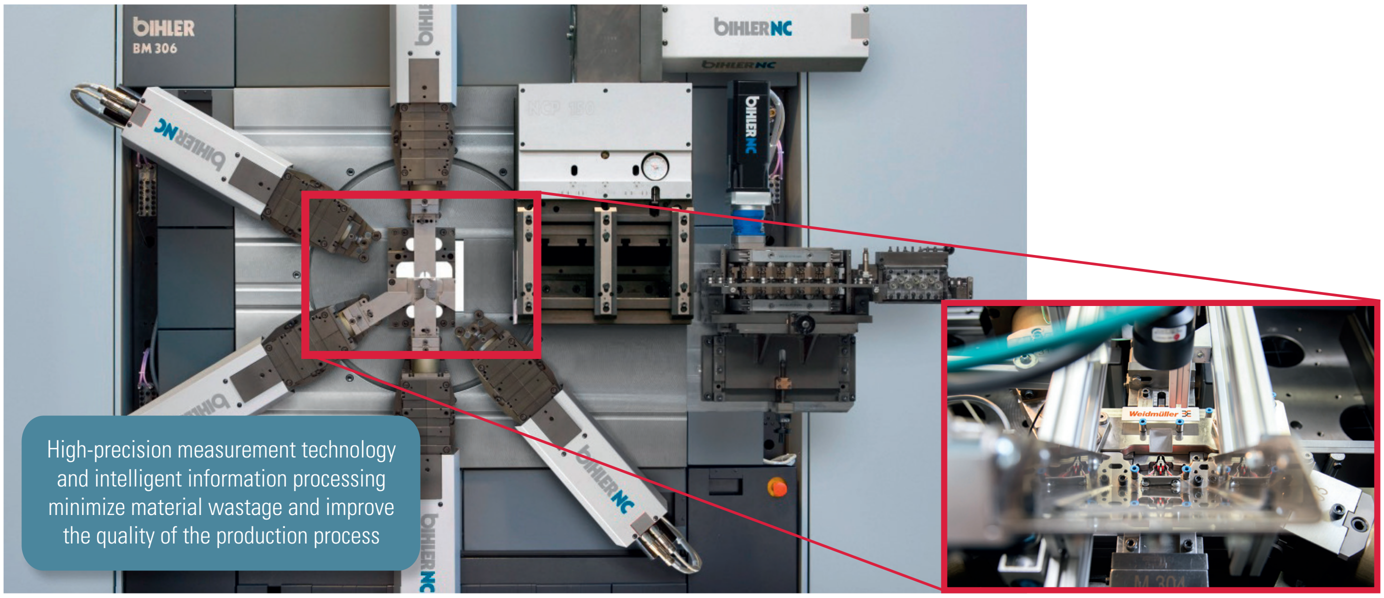

Fig. 9: Self-optimizing press-bending and roll forming machine (Weidmüller, Bihler)

The system thinks for itself, learns and adapts

Cross-sectional project: Self-optimization

The basis for the implementation of the Industry 4.0 concept is the realization of **flexible and configurable production systems.** This can only be achieved through intelligent information processing in machines and systems according to the requirements of the presented technology concept (cf. three-layer model). This will make autonomous interaction with the environment a possibility as well as allow the system to make adjustments to its behavior according to future events.

Future production systems will thus be able to autonomously and flexibly react to changed operating conditions. This goes hand in hand with a flow of information resulting from a significant increase in additional sensor and actuator technology.

Self-optimizing press-bending and roll forming machine

The elements of self-optimization in the **Weidmüller** system (Fig. 9) are high-precision measurement technology, intelligent information processing as well as the networking of the machines. A measurement system within the machine records the key values of the parts to be produced and passes on the information to the control system via the machine output. This ensures that the machine reacts to deviations by autonomously readjusting the tool.

The result is minimum material wastage as well as improved processing quality [Kal13]. In the future, the principle of self-optimization will be able to be applied to entire production lines. The networked machines communicate any irregularities in the process, meaning that outages can be avoided and the production network is able to be optimized overall.

In order to be able to implement self-optimizing processes such as these, it is necessary for autonomous parameterization of the machine or the system to take place. The adjustment to the behavior takes place indirectly via what are known as **system targets.** These represent superordinate system goals and are independently prioritized by the system based on the current situation. Examples of system goals are: "minimize throughput time", "minimize energy consumption" or "maximize quality".

Resource-efficient industrial laundry

The company **Kannegiesser** defines such superordinate goals, e.g. for automation in **industrial laundries.** Depending on the price of energy, the degree of soiling, as well as the workload of the laundry, the goals, "minimize throughput time", "maximize cleaning performance" or "minimize energy consumption" is prioritized. In the case where there is heavily soiled laundry for disinfection, the cleaning performance, for example, will be significantly increased even if this results in increased energy consumption or longer throughput time limits. This means that parameters such as temperature, dosage of cleaning agents or the soaking time will be autonomously adjusted according to need. ■

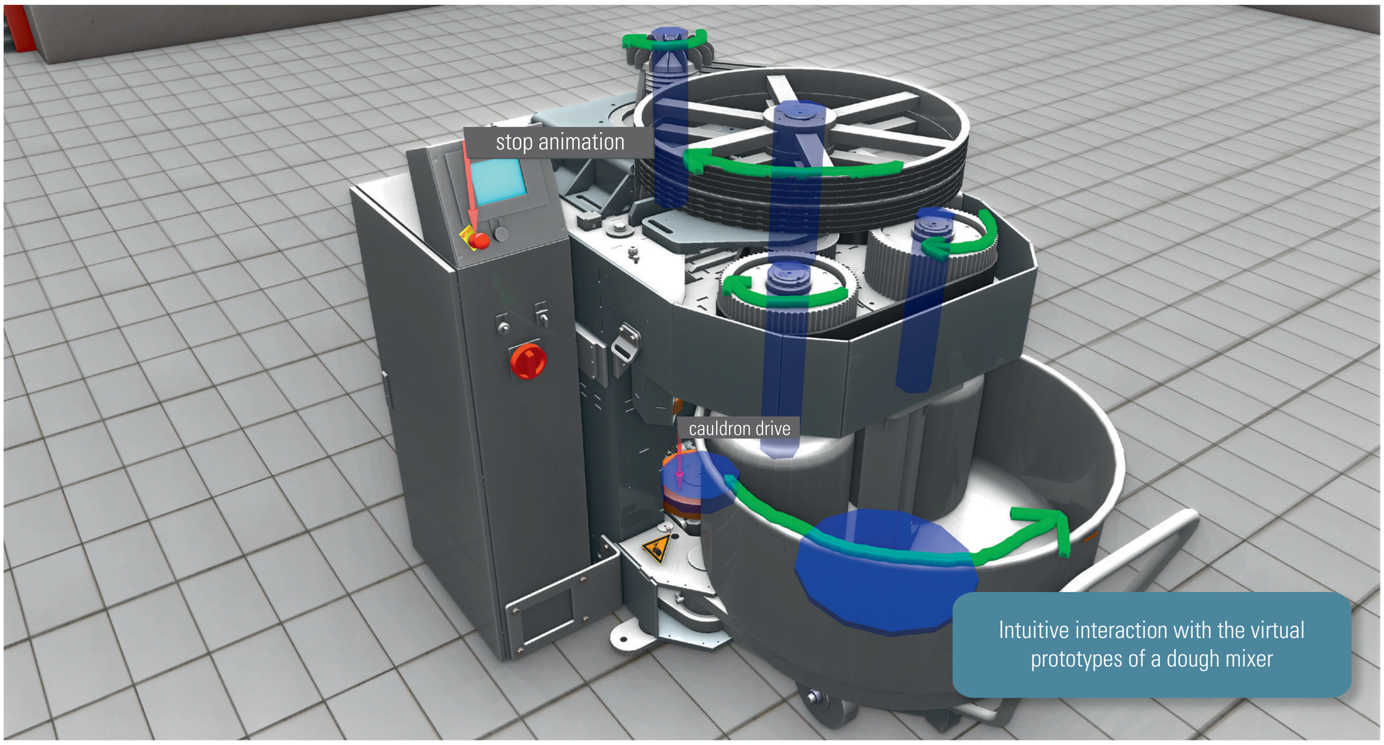

Fig. 10: Virtual design review of an intelligent dough mixer (WP Kemper, Heinz Nixdorf Institute)

Intelligent machines understand people

Cross-sectional project: Human-machine interaction

The increasing penetration of products and production systems with information and communication technology increases their complexity, places new demands on the development and the planning of the systems and requires **new ways of interacting** between the operator and the intelligent systems in operation. The rapid development of modern interaction technologies over the last few years has opened up new possibilities and paradigms for the design of human-machine interaction. Alongside classic text and graphic interfaces, many different types of advanced interaction have also become established, ranging from speech-based through haptic right up to perceptually driven ones (e.g. multimodal).

Thus, e.g. robust 3D tracking of persons, which originated from technology from the entertainment industry, has become available in a short period of time and at low costs. Similar technology leaps can be expected in other areas, e.g. in tactile sensor systems or compliant robot technology.

Transferring this technology to production techniques promises extraordinary success. To make this transfer a reality, the Leading-Edge Cluster has revisited established structures. The Research Institute for Cognition and Robotics (CoR-Lab) and the DFG Center of Excellence Cognitive Interaction Technology (CITEC) at Bielefeld University are developing an **interaction tool kit** [LSP+12], which makes new interaction technologies methods and tools available (for example [KWy+13]) and thus supports the development of application-oriented assistance systems [WEG+13]. Based on this preparatory work, suitable methods will be developed in the Leading-Edge Cluster and made available for technology transfer.

Virtual design reviews in machine engineering

One example is the use of intuitive interaction techniques in **virtual design reviews,** which will make it possible to review the created product, make cooperative design decisions and identify errors. During the development of intelligent technical systems, the analysis of behavior is increasingly gaining in importance – the classic VR representation of static CAD data is not sufficient here.

For this reason, methods are being developed and made available that will make it possible for the developer to describe the **behavior of the system** (e.g. movement sequences) through direct interaction with the virtual prototypes. This will significantly reduce the time and technical effort required for the development of a design review, thus lowering the hurdles for the application of this technique.

Using an example of a modern **dough mixer** from the company, **WP Kemper,** it can be demonstrated how different kinematic functions can be implemented in a virtual prototype based on the CAD data (Fig. 10). Movable parts (mixing hook, motor etc.) can be described with the minimum of effort as well as possible interactions for the developer (buttons, service steps etc.).

Interaction strategies for the operation of flexible production lines

New interaction strategies support the configuration, maintenance and servicing of intelligent technical systems by the employees in the production environment. The **HARTING** company developed, for example, an integrated concept for **flexible production** lines (cf. Fig. 11) in which production modules can be dynamically combined, without the necessity of carrying out manual programming on site.

In addition to the modular system architecture required here, unique concepts for **process-integrated user** interfaces are an essential basis for the interactive description and incremental improvement to the process logic that is necessary for the production task.

Moreover, **interaction strategies** are developed so that faults in the dynamic combination can be easily described via the human-machine interface. Algorithms for machine learning allow the control system of the production modules to adapt.

This significantly improves the flexibility, user-friendliness and cost-effectiveness of adaptable production systems without compromising quality or process reliability. For example, it is expected that on-site production line commissioning costs can be reduced by up to 30% as a result. ■

Fig. 11: Flexible manufacturing through intelligent automation and integration of the employees in the production environment through intuitive user interfaces (HARTING)

Fig. 12: Adaptable production through plug and produce (Phoenix Contact)

Plug and produce

Cross-sectional project: Intelligent networking

An important key for the realization of the Industry 4.0 concept is the extensive networking of the intelligent technical systems up to its integration into the global Internet and the Internet of Things [HJ13]. The focus here is on the adaptability and the flexibility of production through new **self-x-properties** as well as the accompanying implementation of **plug and produce.** Production structures will be more flexible as a result of the partial self-organization of the processes during runtime and will no longer require central planning [NJ14]. Self-configuration is based on methods for the automatic configuration of realtime communication systems and the semantic self-descriptive capabilities of production systems, modules and components. Both aspects will be made available with the support of **service-orientated architecture.**

This can help to significantly reduce and simplify the increasing complexity of commissioning and configuration. As a direct consequence, the operator is free to concentrate on important and value-creating activities. Moreover, reconfigurable communication interfaces make it possible to flexibly integrate intelligent technical systems into different communication networks. To this end, adaptable coordination protocols, which can be verified with reference to their safety properties, make a further contribution to the realization of adaptable production systems.

Another important role is that of **self-diagnosis,** based on networked multi-sensory systems to record their own condition and that of the environment. Sensor and information fusion systems such as adaptive, intelligent sensor systems make possible appropriate adaptive reactions to changes in the systems or in its environment.

The algorithms used for filtering information and for intelligent processing are based on possibilism as well as evidence-theory-based approaches and are suitable for embedding into standardized frameworks. Its ability to be used in realtime in resource-restricted integrated systems can be guaranteed by efficient design.

New methods and supporting tools enable the optimum parameterization of the sensor and information fusion systems without any extensive expert knowledge. Adaptive and intelligent sensor nodes can carry out automatic parametering through the identification of context-based connections and thus increase the flexibility and reliability of the fusion system. Moreover, they possess self-descriptive capabilities and interfaces for realtime communication, which guarantee the ongoing networking of the sensor system.

Moreover, **standardization** in this area takes on a central importance to ensure the interoperability of systems from different manufacturers, on the one hand. On the other hand, successful integration into the value-added network, thereby making it possible for the systems to collaborate, can only be achieved with the help of joint standards. The existing architecture and methods are therefore immediately integrated into the standardization. The following application cases illustrate the methods and concepts developed.

Manufacturing different products with flexible machinery

The company **Phoenix Contact** was able to create an **adaptable production system** by making use of intelligent automation technology, which facilitates simplified planning, commissioning and quick adaptation to new requirements (Fig. 12). In particular, it is no longer necessary to take into consideration all manufacturing variations during the design on the system.

The focus of work is on the vertical integration of the system modules into existing IT systems and intelligent control and communication technology, which support automatic configuration during the planning and operation phase, thus reducing engineering efforts.

A further aspect is **intelligent products** with a digital article description basis. They know their planned value-creating sequences, can communicate with the production system and can be clearly identified at all times. Information along their life cycle is collected and, if required, made available.

Manufacturing and assembly processes are able to be planned, monitored and controlled based on this product-inherent information. Quality can thus be significantly increased and wastage reduced. Moreover, methods of **image-supported evaluation and quality control** in production systems integrating the digital information of the product are being developed. The results obtained are implemented and validated in real pilot systems.

Intelligent adaptation and networking of agricultural machinery

Agricultural machines are complex production systems, which are required to quickly and efficiently bring in an optimum harvest. To do so, machinery operators must take into consideration the conditions of each field, such as crop ripeness or soil conditions. At the same time, individual processes such as harvesting, transport and storage must be optimally coordinated. The company **CLAAS**' aim is to develop a software-based service that allows different agricultural machinery to autonomously adapt to current harvesting conditions and intelligently link individual processes and participants (Fig. 13).

Ensuring the optimal load for the agricultural machines requires the involvement of all participants in the harvesting process, such as manufacturers, contractors and farmers. It is estimated that utilization of agricultural machinery can thus be increased by at least 10%. Autonomous adaptation also makes the machinery easier for drivers to use as they are no longer required to make manual changes during the harvesting process. The software-based service can be transferred to other applications such as transport logistics. ■

Fig. 13: Process optimization through the intelligent networking of agricultural machinery (CLAAS)

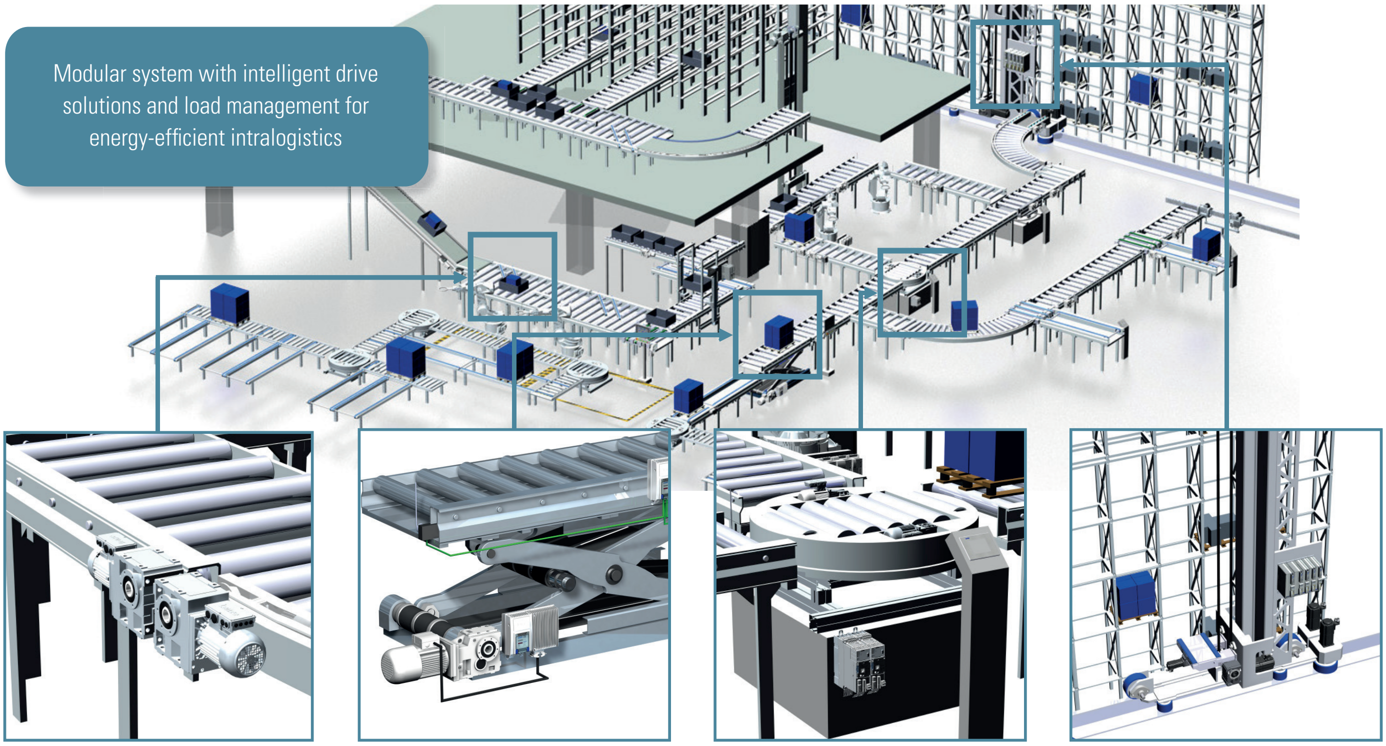

Fig. 14: Energy-efficient intralogistics through efficient drive solutions (Lenze)

Lower energy consumption, higher performance

Cross-sectional project: Energy efficiency

The efficient handling of the existing resources, in particular the required energy is another important aspect of the Industry 4.0 concept. The overarching goal is the holistic **optimization of manufacturing processes** with reference to their productiveness, efficiency and resource efficiency. The optimized management of energy consumption and energy generation combined with the corresponding flow of power make it possible to carry out energy and load management in an intelligent technical system.

The combination of process data from production plants and the corresponding energy profile make it possible to gain an overall view and optimize the plant using behavior-based models. Networked systems (smart grids, micro grids etc.), which are connected with their environment in an energy exchange, are becoming increasingly more relevant and are also playing a central role in optimization.

Energy-efficient intralogistics through intelligent drive and control engineering

Intralogistics is being utilized in an exemplary application by the **Lenze** company (Fig. 14). Today's intralogistic systems consist of fully automated warehouse and distribution systems, whose energy consumption is mainly caused by electric drives. Energy-efficient solutions have only rarely been considered due to cost reasons. However due to the increasing cost of energy, energy consumption has now become a significant cost factor.

The use of intelligent drive and control technologies and intelligent load management offers considerable potential for optimization and makes the energy-efficient operation of warehouses possible. Accordingly, this ensures sustainable development.

A **modular system** provides efficient drive solutions and the corresponding design tools, making it possible to provide the most environmentally-friendly and economical solution for every warehouse drive process. Moreover, further optimization is able to be achieved through load-dependent flexible movement profiles, which require adaptable controlling and the intelligent networking of the different components.

Intelligent load management optimizes warehouse operation in process realtime with relation to peak loads. This makes it possible to implement the best possible distribution of the power network load. This facilitates the better planning of the supply network stability, which is of crucial importance, particularly for optimal operation in future electric power networks (smart grids).

Pilot runs using prototypical implementations are carried out using demonstration models, such as the Lemgoer Smart Factory, and validate the developed methods and concepts.

Sustainable production through intelligent automation technology

Intelligent automation solutions are important levers for a production process that conserves resources and is thus energy efficient. The **integration of intelligent processes and technologies**, such as self-optimization, learning processes, condition monitoring and image processing, offers great potential in classic automation engineering.

The **Beckhoff** company is developing a platform in this area to support the development and operation of sustainable production systems and thus contributing significantly to the optimization of energy efficiency (cf. Fig. 15). The core of the platform consists of **reusable solution elements** in the form of hardware and software components that provide intelligent functions for automation engineering.

The use of these types of solution elements will mean that the energy consumption of production systems can be reduced in the future by at least 10%. Moreover, the productivity and reliability of production systems will be increased while the costs of the automation technology will remain almost the same. ■

Fig. 15: Intelligent automation solutions for sustainable production (Beckhoff)

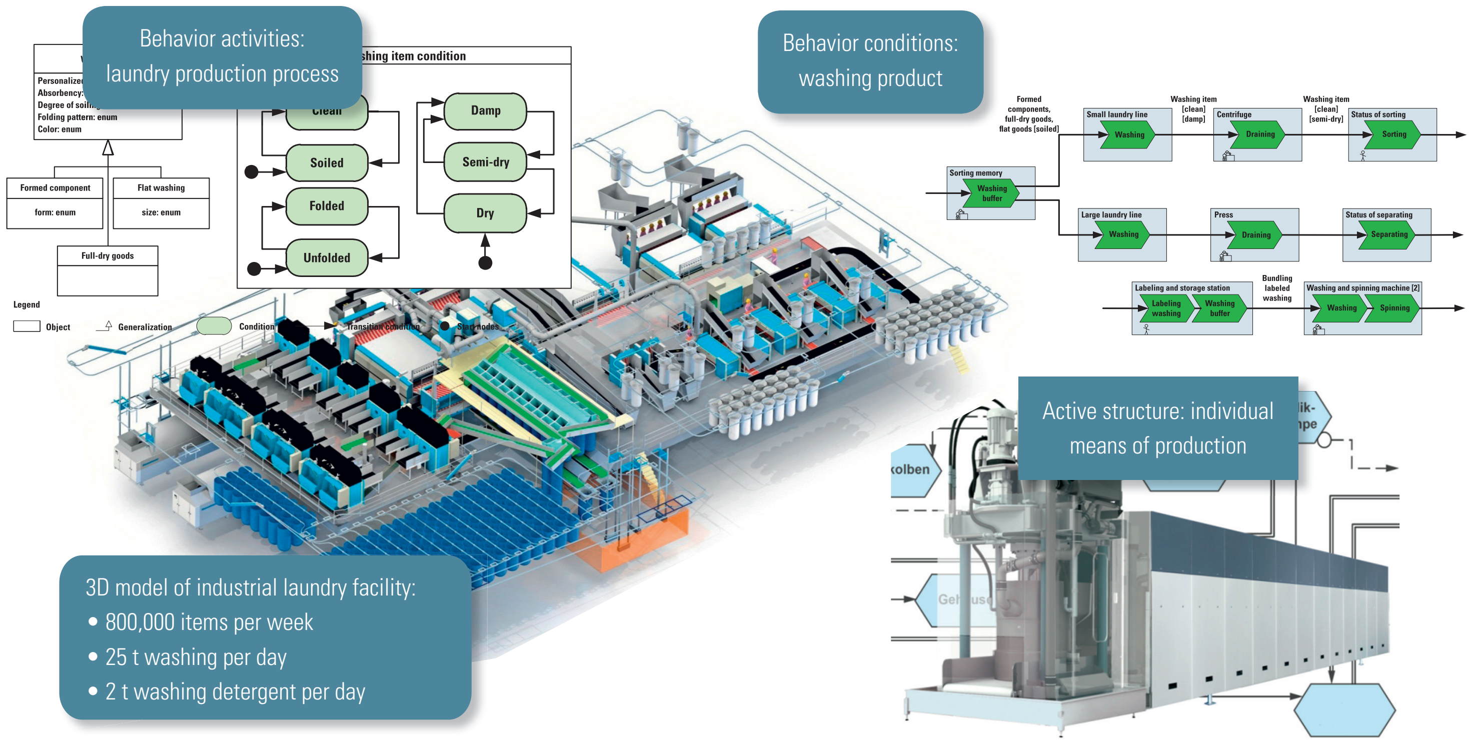

Fig. 16: Modeling for optimizing the resource efficiency of industrial laundries (Kannegiesser)

Intelligent products require intelligent development

Cross-sectional project: Systems engineering

Systems engineering (SE) is a universal, interdisciplinary field of engineering that focuses on the development of technical systems and integrates all aspects. It focuses on the multidisciplinary system and includes the entire lifecycle of all development activities. Today, systems engineering is more a collection of methods than a comprehensive holistic method for the creation of technical systems [GDS+13]. Nevertheless SE, as represented by Ropohl amongst others [Rop75], is the appropriate approach for the required methodology for the development of complex technical systems within the context of Industry 4.0.

The goal is to make it possible to **design a holistic interdisciplinary complex system** that, in the course of further integration, will flow into the established development methodology and the corresponding tool environment of the specialist areas concerned, such as mechanics, electrical engineering/electronics, software technology as well as equipment and process technology.

Universal, interdisciplinary product and process modeling

The **Kannegiesser** company's aim is to significantly improve the resource efficiency of **industrial laundries.** This includes the best possible utilization of resources such as energy, water and washing detergent, while at the same time optimizing time and costs and ensuring the environmentally-friendly cleaning of the items washed. The entire laundry is to be designed, constructed and operated according to ecological and economical principles.

Within the scope of this project, new **modeling and simulation paradigms** are being developed, which will help cross-system process planning, control and monitoring to be optimized. As presented in Fig. 16, the industrial laundry will be modeled at different levels of abstraction.

The process and system models describe the systemic, IT and physical behaviors of the subsystems – from the laundry product through the individual means of production up to the entire laundry production process.

The ongoing use of this model during the planning, control and modeling process makes it possible to identify sub-optimal conditions early in the process and implement optimization in a targeted way. The methods and tools developed within the scope of this project can be applied to other similar problems of complex mechanical engineering systems.

Integration of the virtual and real world

The company **DMG MORI SEIKI** is striving to support production planning/NC programming with the aid of a **virtual tool machine** (Fig. 17).

The selection of the most economical manufacturing processes as well as the optimal processing strategy is a part of **production planning** and is heavily based on the practical knowledge of the employees, who are supported by NC programming systems.

This however often does not adequately reflect the behavior of the machine; thus, for example, the dynamic properties of the axes or tool changes are simplified or neglected.

Aided by a **virtual reproduction** of the real machine, in the future the underlying manufacturing documents will be able to be optimized through simulation before it is transferred further to the workshop. Moreover, the practical knowledge of the production engineer and the results of the optimization can be transferred for re-utilization operations into an integrated knowledge base [BGP+13]. ■

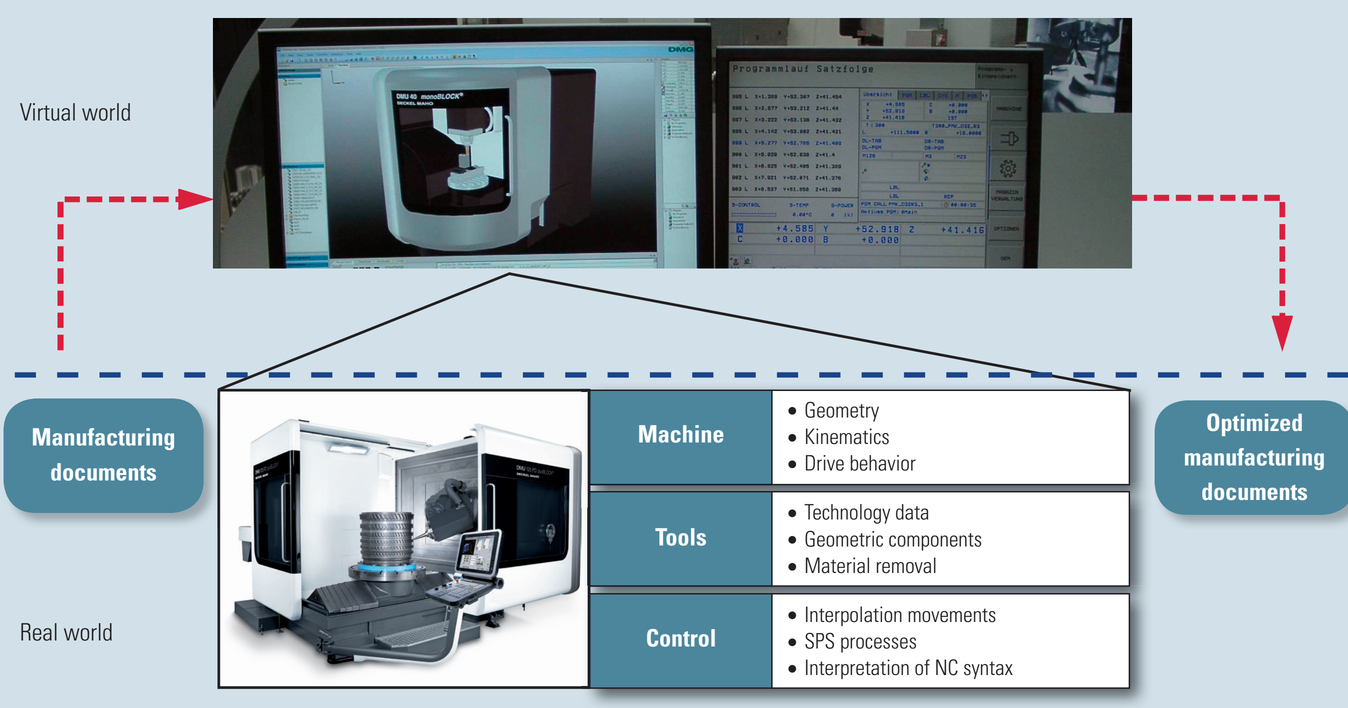

Fig. 17: Optimizing manufacturing documents using the virtual tool machine (DMG MORI SEIKI)

Summary and forecast

it's OWL has what it takes to take the path to the fourth revolution step by step.

With a cluster structure strongly characterized by mechanical and system engineering as well as the electrical industry, it's OWL embodies the **dual strategy** propagated by the national platform Industry 4.0, which views Germany as a leading market as well as a leading supplier.

The cluster companies Beckhoff, Harting, Phoenix Contact, Wago and Weidmüller, for example, are setting standards in the area of industrial automation and hold 75% of the global market share for electronic connector technology. Set against this is a strong base of mid-sized mechanical and system engineers who can look forward to considerable potential for innovation as a result of applying intelligent technical systems.

Supplemented by a strong research community, it's OWL pools expertise and demand. With its implementation of practical innovation projects within the context of intelligent technical systems, the cluster offers the ideal conditions to join in shaping the transformation of industrial production and **contribute significantly to the realization of the Industry 4.0 concept.**

As the majority of the production companies in **OstWestfalenLippe** (as in other parts of Germany) are small and mid-sized companies, the realization of the Industry 4.0 concept is highly dependent on their innovative strength. For this reason, it's OWL operates a consistent transfer strategy with the goal of distributing the described technology platform to the masses.

It is intended that this technology transfer primarily be achieved by the so-called focused transfer projects. These are smaller projects that run from five to ten months and within which the introduction of cluster technologies is supported. One hundred and twenty of these transfer projects will be implemented over the next three years; the project volume comprises a total of approx. 10 million euros. ■

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it's OWL e.V. bundles the interests of companies, research institutions and transfer partners.

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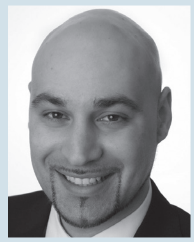

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