

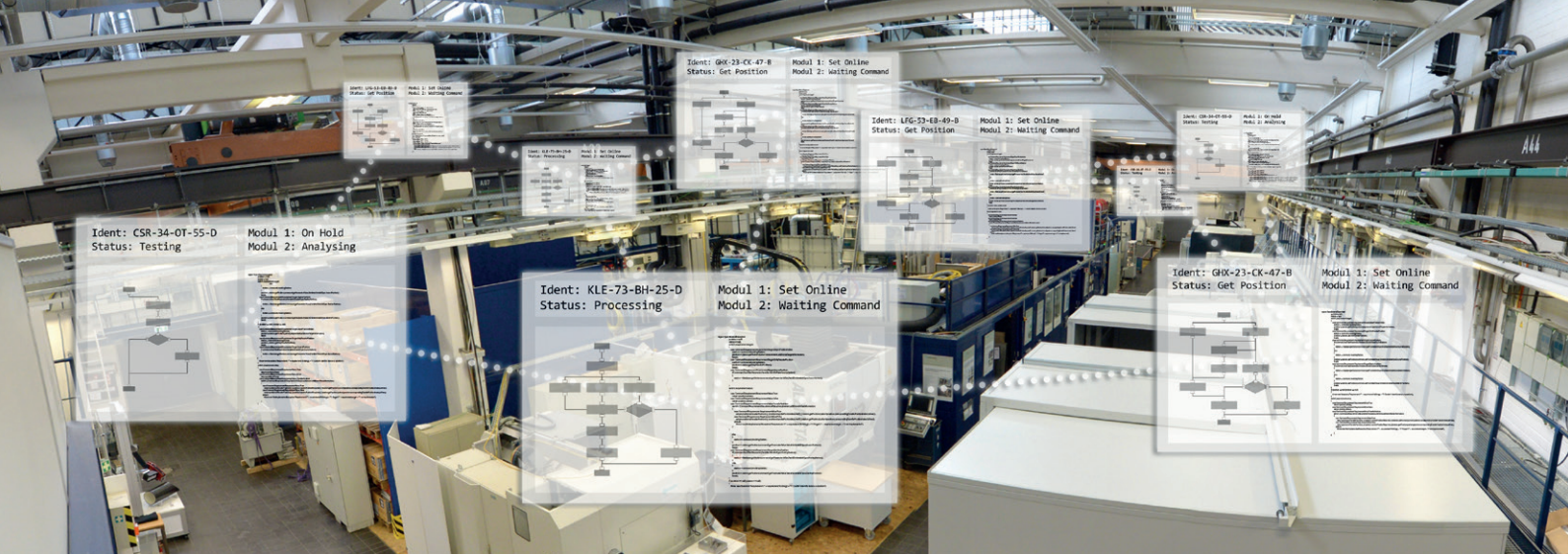


Fraunhofer

NETWORKED, ADAPTIVE PRODUCTION

INTERNATIONAL COMMUNITY FOR THE DEVELOPMENT OF APPLICATIONS AND TECHNOLOGIES IN INDUSTRIE 4.0





NETWORKED, ADAPTIVE PRODUCTION

“What does Industrie 4.0 mean for my production systems and what do I have to do to make my company fit for the future?” This is a question we frequently hear from manufacturers in Germany or anywhere else in the world. There is no simple, one-size-fits-all answer. It seems safe to expect, however, that increasing levels of digitalization in manufacturing environments and big data analytics will shape today’s manufacturing processes, subjecting these processes to radical changes which will make them leaner, sharper and more efficient.

The three Aachen-based Fraunhofer Institutes and other experts from industry and research have established the “International Center for Networked Adaptive Production” (ICNAP) to find out which new approaches in information technology can lead the way towards Industrie 4.0 and which requirements must be met.

A joint effort to explore and develop Industrie 4.0 technologies for sophisticated value chains

Under the umbrella of the ICNAP, the Fraunhofer Institutes for Production Technology IPT, Laser Technology ILT and Molecular Biology and Applied Ecology IME are cooperating with the RWTH Aachen University and renowned industrial partners to develop Industrie 4.0 production systems and value chains before validating them in actual production environments, the so-called pilot lines.

The ICNAP Community is focusing its efforts on five fields of research:

- Predictive analytics for adaptive process chains
- Digital twins in product life cycles
- Big data analytics in complex production environments
- 5G data transmission in production systems
- Cloud technologies and edge computing in the Smart Manufacturing Network

The ICNAP was established through a joint initiative of the government in the federal state of North Rhine-Westphalia and the Fraunhofer-Gesellschaft with active support from German industry. Founded in late 2016 as the Fraunhofer High-Performance Center for “Networked, Adaptive Production” in Aachen, it was provided with a three-year budget of 6.4 million euros with a view to designing an open research platform and industrial test environment in which innovative approaches of digital production could be developed and evaluated under realistic conditions.

INDUSTRIE 4.0 FOR YOUR COMPANY

The ICNAP Community aims to find more flexible and efficient ways of designing sophisticated value chains for the manufacturing of complex and customized products. We do not believe that the development and improvement of production technology as such represents our main challenge: this is the brief of our three existing institutes which already cover a wide range of technologies. ICNAP has instead been set up to demonstrate and to validate the potential benefits of digitalization and research cooperation for a wide range of technology products, production processes and corporate networks.

The digitalization and networking of individual items of technological equipment or even entire biotechnology facilities, of data streams, data formats, data standards and interfaces creates the space in which ICNAP can operate as a mediator between different dimensions: the real world of components, tools and machinery and the virtual world of process data and component specs.

Companies can still become ICNAP partners, participating in its projects and benefiting from the latest research results: by joining our exclusive community, they get an opportunity of contributing to the design of selected development projects, of establishing networks with other pioneers of Industrie 4.0 and of exchanging views and experiences with scientists and companies at the interface of IT and production technology.

There are three ways in which you can benefit from our developments:



Seize the opportunity: Join the ICNAP Community

Your membership in our exclusive moderated research community will provide you with access to the latest research results and sophisticated technology infrastructures. Community membership enables you to conduct joint as well as individual research projects with or without the involvement of other ICNAP partners.



Take part: Initiate new projects with your fellow community members

You are free to use the results of the ICNAP research and development projects either in conjunction with other partners or exclusively for your own company. You can test your own IT solutions in the existing ICNAP pilot lines, expanding the performance range of the test environment. It is also possible, however, to create additional pilot lines that are customized to your specific needs and requirements.



Take action: Start your own corporate projects

ICNAP developments may also be individually realized and implemented in your company. You are free to base any such project on insights and developments of the ICNAP that can be customized – by us and other technology providers from the community – to the specific needs and requirements of your business.

OPPORTUNITIES FOR COOPERATION

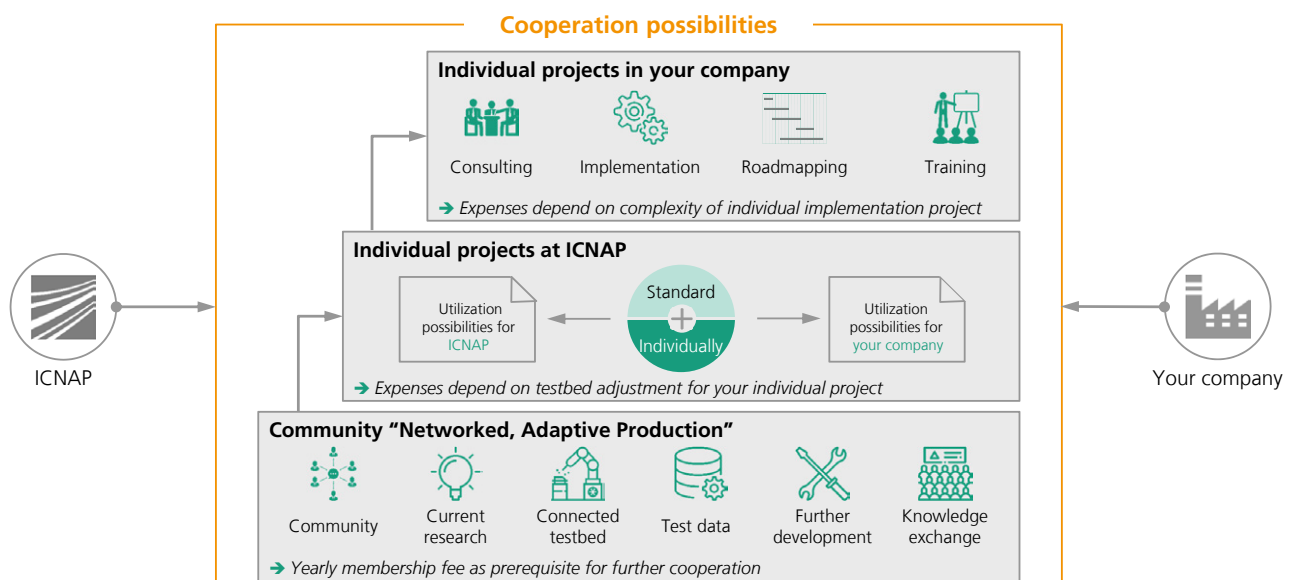
MEMBERSHIP IN THE “NETWORKED, ADAPTIVE PRODUCTION” COMMUNITY

Many of today's future-oriented businesses are still searching for competent partners and service providers who are sufficiently familiar with the requirements and specifications of Industrie 4.0 to help them on their way into a sustainable future. Is it enough to provide all their machines and items of equipment with Internet technology, to establish process parameters and to transmit status messages? Or should they aim to achieve a full digitalization of their production lines, using real time analyses to identify potential sources of error and staying continuously in the optimum corridor of their manufacturing processes?

The network of partners in our moderated research community provides you with access to the results of fundamental

research and practice-oriented development efforts: You will not only benefit from the release of production data and software developments (which you will be able to test in your production systems) but will also be able to take advantage of a fully networked test environment in one of Europe's most modern and versatile machine parks. Sophisticated sensor systems, fast wireless 5G data transmission and connections to Fraunhofer's “Virtual Fort Knox” cloud are already available and have been fully integrated into the test environment.

Your membership will open your company's door to additional opportunities of technological cooperation and allow our partners in the ICNAP to continue the development of Industrie 4.0 across a wide range of applications.



RANGE OF SERVICES FOR MEMBERS OF THE ICNAP COMMUNITY

Not only can members of the ICNAP Community help to shape development projects and the topics they address; they can also network with other Industrie 4.0 innovators or exchange ideas and views with companies, engineers and scientists at the interface between IT and production technology. Parallel to this, they can participate in studies and work groups to discuss and work through selected topics together. Members are granted access to test data obtained in the course of ICNAP projects and are kept up to date on the latest developments

via newsletters. They can take part in workshops, seminars and annual community meetings or source new partners via an exclusive portal. ICNAP also hosts an annual hackathon, which draws on the combined creative potential that exists in and around the RWTH Aachen Campus for the development work: students and graduates take on the latest challenges facing Industrie 4.0 and demonstrate their skills by completing practice-based programming tasks in an actual manufacturing environment.



INITIATE NEW PROJECTS WITHIN THE COMMUNITY

Modern high-performance machines are still operating like black boxes. The global IT community – with its strong commitment to open source software and free licences – has long ceased to question the principle of open standards. Heavy engineering and machine manufacturers, meanwhile, remain reluctant to provide transparent definitions of process, component and control operation data that would allow other companies to integrate such data into their own systems and data processing streams. Good and open cooperation, however, can transform individual contributions into a whole that is not only greater, but also far more valuable than the sum of its parts.

We and our community would like to help you to open the black box of your manufacturing machinery and processes. You will decide which of your data you want to share: we provide you with the opportunity of customizing our standard test environment to your specific conditions and requirements within the mutually agreed projects. Your contribution to the costs will depend on the extent and complexity of the required effort and on your chosen form of the project's commercial exploitation.

If you opt to protect the results of individualized projects as your company's exclusive intellectual property, you alone stand to benefit. If, conversely, you are prepared to share selected production data in the jointly used community cloud, you will also support your ICNAP partners, making a valuable contribution to the overall progress of Industrie 4.0.

By making test data from actual production processes available, the ICNAP creates perfect conditions for the development and evaluation of new solutions – without any need for you to put further stress on your corporate resources. The test environment of the Fraunhofer IPT thereby addresses a central problem that is generated by the implementation of Industrie 4.0 technologies, allowing you to avoid costly downtimes of your production equipment while you are developing new solutions.

On top of that, we offer IT providers the opportunity of implementing their hardware and software products in a sophisticated test environment. This allows you not only to support us in the expansion of the range and the performance of the test environment, but also to test your own systems for their functional efficiency, reliability and flexibility under highly realistic conditions.

START YOUR OWN CORPORATE PROJECTS

The wish to convert the results of top-level research and development into practical industrial applications is what drives our scientists and engineers. Fraunhofer is known for its determination not to let innovative ideas gather dust on academic bookshelves but to develop them into marketable products that can create added value both for their manufacturers and for our society as a whole.

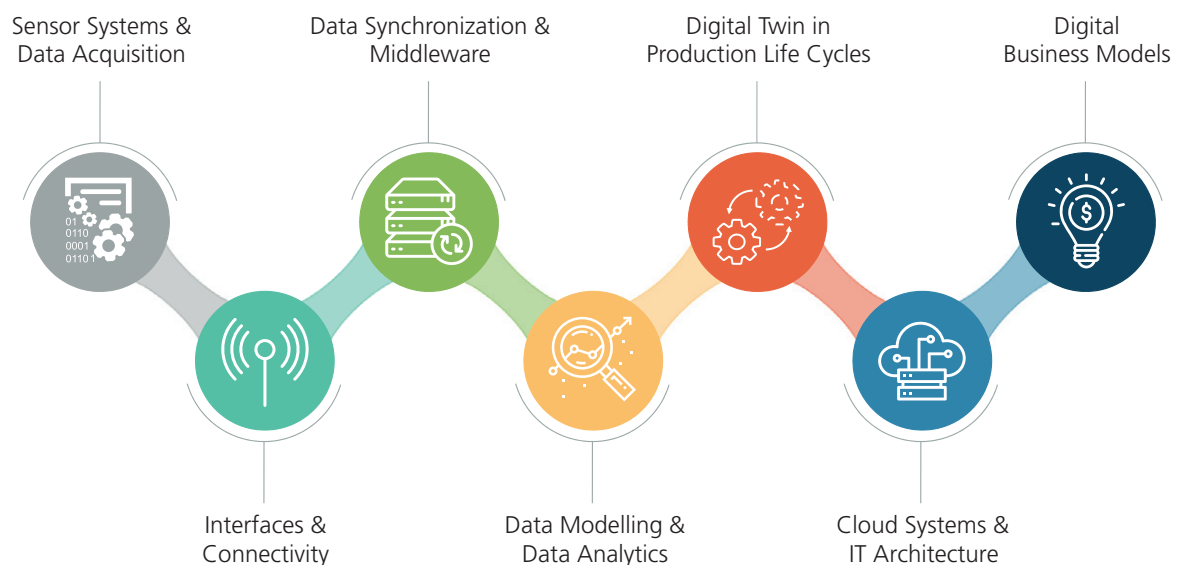
This is why we are committed to paying consistent attention to the business potential of the ICNAP's research and development efforts, right from the drawing board stage. We want to help you set up a realistic roadmap for the implementation of the results in your company – at an early stage of the process.

If you decide to conduct an individual ICNAP project with one or more of the Fraunhofer partners, we can assist you, managing the process of developing and practically implementing ideas from the design stage to the transfer of the newly acquired knowledge to your workforce, with or without the involvement of cooperation partners from the community (this is for you to decide). Your contribution to the costs of any such customized project whose commercial results are going to be exclusively enjoyed by your company will depend on the extent and complexity of the required effort. Any such fee will be amicably agreed.

AREAS FOR DEVELOPMENT IN ICNAP

FROM DATA ACQUISITION TO A DIGITAL BUSINESS MODEL

To ensure that value chains for manufacturing of complex and customized products can become considerably more flexible and efficient than before, ICNAP places research questions affecting seven subject areas at the focus of its development efforts



Sensor systems and data acquisition



How are all relevant data along the entire process chain collected?

Data acquisition is the first step on the way to networked, adaptive production. It is vital to establish which data can be recorded directly in the control unit of the production machine concerned and which can only be obtained via additional sensors. When additional sensors are required to measure parameters such as temperature, speed or pressure for example, these must be integrated robustly and reliably within the manufacturing process.

Data synchronization and middleware



How are raw data time-synchronized and enriched with information?

Once communication has been established within the production process, it is essential to determine how to standardize procedures for filing data from various sources simultaneously and at various recording frequencies. The quality of the different sources and the required level of data accuracy are also defined at this point in order to facilitate accurate comparison and evaluation of analysis results within the networked production environment.

Interfaces and connectivity



How do the key players involved and systems communicate with one another during the production process?

When the production data are reliably recorded, a suitable communications protocol such as MQTT or OPC-UA is selected and the decision is made as to whether communication should be via wired or wireless connection. The ICNAP partners scrutinize the data transfer requirements in terms of data throughput and latency for the production process in hand and can already issue recommendations at this point.

Data modelling und data analytics



How are the relevant data selected and what methods are used to obtain information from that data?

To provide even better support to staff working in manufacturing companies – from production planners through quality managers to machine operators – whenever they have decisions to make, it is vital to define which process chain data are relevant specifically to them. This is achieved by modelling the actual process digitally on the basis of the data obtained. Information can be generated from the data underpinning the structure of process knowledge using suitable data analytics methods in the form of machine learning algorithms or correlation analyses.

Digital twin in the product life cycle



How is information and know-how at different stages in the product life cycle brought together digitally and visualized?

Before the information recorded and the know-how acquired in the course of the entire value chain can be stored and used, the relevant data have to be brought together and set in relation to one another. The outcome is a digital image of the actual process which can be used to visualize these data in a goal-oriented and user-friendly form. Recommendations for action and feedback strategies for production can be derived from the knowledge obtained about the process.

Digital business models



How are digital business models developed and integrated within the traditional product and services portfolio?

Not only does networked, adaptive production improve production by making additional knowledge available but it also opens up the possibility of completely new forms of economic value added via extended or completely new physical processes and products. Digital and data-based business models can be developed, classified and evaluated even for digital services such as machining-as-a-service or power-by-the-hour.

Cloud systems and IT architecture



How is the most suitable infrastructure selected and the existing systems connected to it?

An efficient IT architecture is vital to the successful integration of digital tools in production. To this end, ICNAP tests matching database and cloud systems for in-company or cross-company networks, taking account of current safety standards, norms and regulations.

EXAMPLES OF THE APPLICATION OF INDUSTRIE 4.0

PREDICTIVE ANALYTICS FOR ADAPTIVE PROCESS CHAINS

Digital assistance systems and technology apps in networked adaptive production operations help the engineers to monitor the data, to control process conditions and to apply their personal skills and competences with maximum efficiency. Visualization tools such as smartphones, tablets and smart glasses can provide immediate information, allowing flexible adjustments and quick changes of production plans or processes.

Data from model-based simulations optimize the decision-making about possible improvements of products and processes. The software detects critical situations during the manufacturing process and accounts for frequent changes of product specifications in the production of prototypes or small series, allowing the process planning to reach high levels of efficiency even before the first component leaves the production line. Constant checks and comparisons of real data and matching simulation data ensure that the models are continuously improved, with direct benefits for the quality and performance of the end product.

Predictive process chain design in tool manufacturing

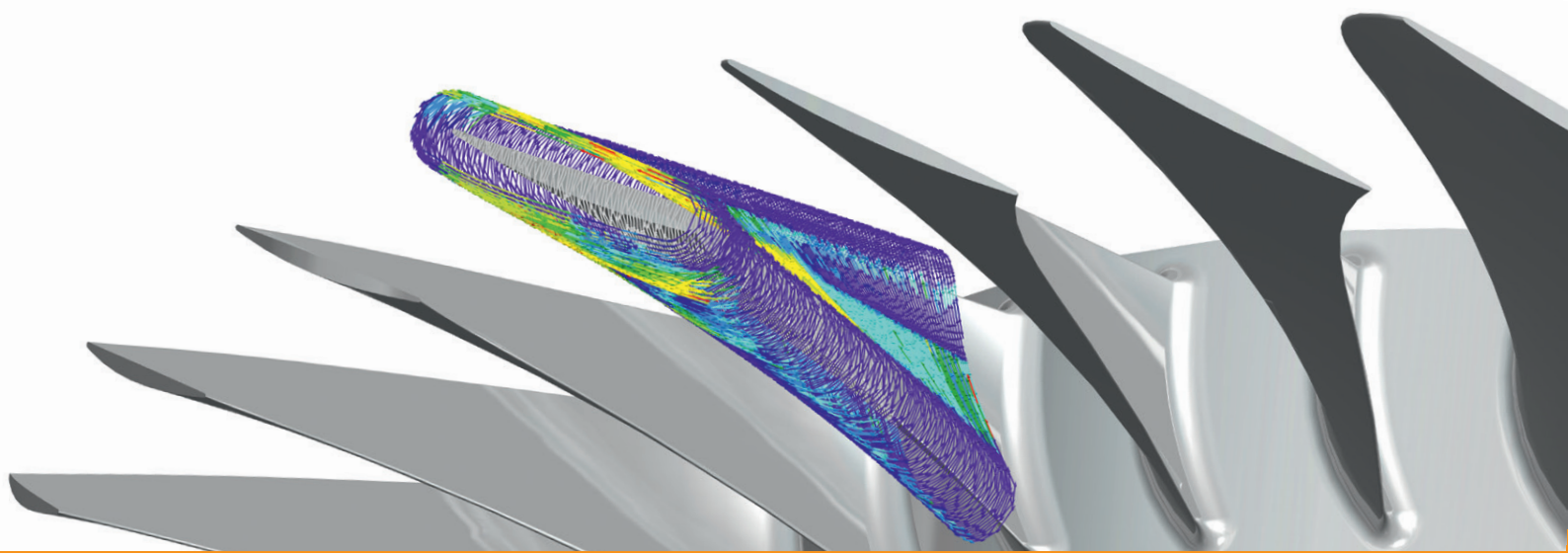
The key element in the tool manufacturing process is the production of a prototype which requires the successful implementation of the "First Part Right" principle. On the basis of different process chain models, engineers provide estimates for the duration of the individual processes, the component quality and the manufacturing costs. By adapting process chain plans to different manufacturing conditions, it is possible to predict the results of the production process under review with significantly higher levels of precision.

Flexible design and production of battery modules

The adaptive production of battery modules accounts for given restrictions such as spatial conditions, weight and properties including energy and power. Different types of cells are used in the production of small to medium-sized series of modules. Laser beam welding and laser bonding are applied in the manufacturing of connecting elements. Process information and data are immediately integrated into the design process. An integrated technology and configuration application supports the – fully digitalized – process of designing systems and manufacturing processes.

Objectives

- Predictive planning of concrete process chains and processing sequences in view of specific result targets
- Better, more profound understanding of the processes involved through more accurate simulations of the individual process steps using recent real data
- Higher levels of component quality and shorter manufacturing times by adjusting downstream process steps
- Earlier recognition and automated correction of errors through online adaption in ongoing production processes



DIGITAL TWINS IN PRODUCT LIFE CYCLES

The main objective of all processes to manufacture high-tech products is compliance with the specified ranges of permissible variation. For this purpose, all data must be recorded that might provide some evidence of status changes anywhere along the process chain. Sensors in machinery and equipment can provide valuable clues as to whether or not the actual values will fall into the tolerance range.

All data from the sensors and the production system will be stored individually for each product, creating a digital twin that retains a full production history including project data and order specifications. Identification systems allow this twin to be assigned to the individual component, making it available for every downstream process step. The extended product data models provide relevant, context-specific data from the manufacturing history for further analyses, accelerating process development and process optimization in the production of prototypes as well as large series.

A specific time and place must be recorded for each set of sensor data about default process parameters, the temperature in the hall or machine vibrations. This still provides technological challenges, but the causes of certain defects can be revealed only if the process can be fully traced back.

Mass production of turbine components

More efficient process chains and the provision of evidence for the compliance with certification requirements: these are the objectives of real time production data generation in the mass production of turbine components. The data are gathered through the use of standardized interfaces and are available for simulations and documentation purposes along the entire process chain.

Production and repair of gas turbine blades

Experiences with the application of virtual planning tools such as process simulation and process chain reconfiguration for additive and subtractive manufacturing or repair processes including milling and laser metal deposition (LMD) are analyzed to establish their potential use in the production and repair of gas turbine blades. By providing detailed logs of real data from the processes under review, it is possible to recognize patterns which reveal where adjustments along the process chain may be beneficial. Optimized planning tools benefit from data consistency and ensure high levels of transparency in the planning process.

Objectives

- Detailed recording and storage of all relevant process data from the manufacturing chain
- More immediate use of information about manufacturing errors and component defects to identify the critical manufacturing steps
- Customized and adapted repair processes based on the knowledge of entire product histories throughout the product life cycle
- Higher levels of machine availability, lower downtimes and quicker response times following breakdowns through predictive maintenance of machine tools

BIG DATA ANALYTICS IN COMPLEX PRODUCTION ENVIRONMENTS

Complex manufacturing processes with particularly high quality requirements can benefit enormously from a detailed knowledge of all existing data and from the resulting insights into influencing factors and variables. Analyses of large data volumes can serve to convert information into predictive models, which then allow the configuration of processes within a range of optimum parameters. These ranges are customarily defined to lie safely within the specification limits while, at the same time, allowing high yields.

Biopharmaceutical production processes provide a particularly suitable test environment for the technological potentials of big data analytics. One example is the technique of producing antibodies. Antibodies are first generated in botanical plants before they are converted into a biopharmaceutical product through a cleaning process. Since the growth of plants is determined by many factors including light and temperature and since the growth rate in turn determines key pharmaceutical parameters such as stability and effectiveness, a profound understanding of the underlying processes is vital. Such an understanding can be gained from data-based models that allow a batch-specific adjustment of the conditions of the plant cultivation process.

The highly flexible and adjustable analytic tools and models that are developed by the ICNAP can be used in a wide range of fields where production conditions must be frequently adjusted, for example across the entire process industry including pharmaceuticals, cosmetics and agriculture. Intelligent analytical methods can also be highly useful in classical discrete manufacturing environments where large and highly heterogeneous data volumes must be processed. Under such circumstances, predictive models can serve to establish and to eliminate potential error sources at an early stage.

Upstream production and downstream processing: from the sowing of seeds to the biopharmaceutical product

The so-called upstream production process, i.e. the process chain “sowing of seeds – growth – harvest”, benefits from big data analytics, which allow the continuous optimization of plant growth and expression levels of the desired substances as well as the increased generation of recombinant protein. The later so-called downstream processing – the process chain “extraction – cleaning – biopharmaceutical product” – not only uses the process parameters from the upstream production but also additional parameters (such as turbidity, pH and conductivity) to improve the process models with the objective of achieving higher yields, higher quality levels of the biopharmaceutical product and more reliable monitoring techniques.

Objectives

- Transformation of big data into smart data through contextualization
- Accelerated product release through comprehensive, integrated process simulations
- Strict compliance with ideal process requirements through automatic establishment of key reference variables and continuous target-actual comparisons even in highly complex production environments
- Faster and more precise adjustments to changing manufacturing conditions
- Improved utilization of production line capacities even for small batch sizes

EDGE COMPUTING AND CLOUD TECHNOLOGIES IN SMART MANUFACTURING NETWORKS

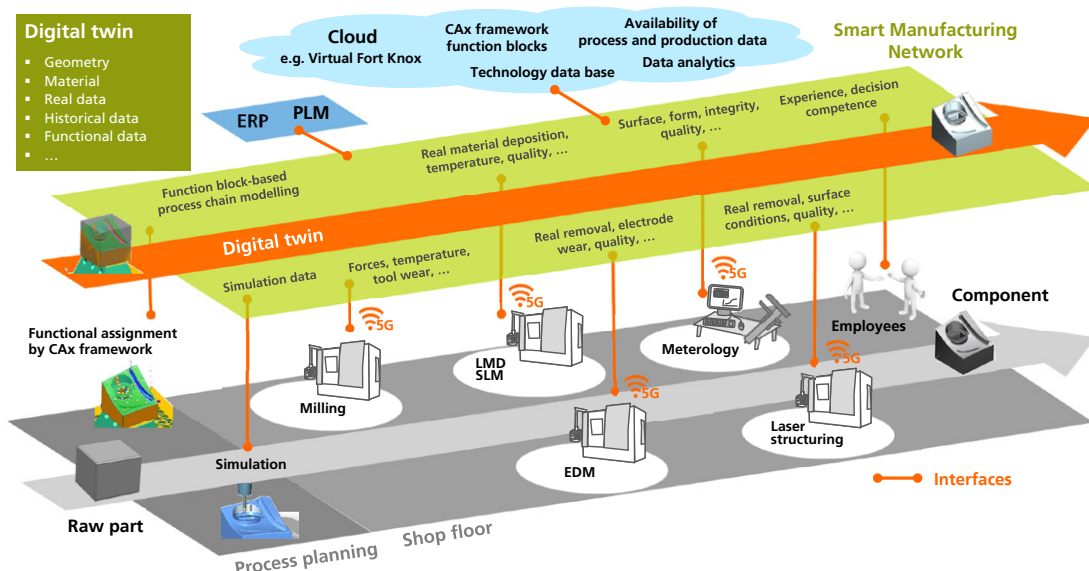
At the heart of the ICNAP, the “Smart Manufacturing Network” provides an environment in which machines, production systems, databases and simulation systems can communicate with each other and share their data and services in a jointly used cloud. In addition to the commonly used, commercially distributed cloud architectures, partners can also access the “Virtual Fort Knox”, which has been developed by Fraunhofer – its servers are located at the Fraunhofer IPT in Aachen – as an independent and safe cloud system for manufacturing applications. Human users use mobile devices to access the process and can interact with all subsystems, control these systems or request specific data.

Such decentralized and modular systems allow engineers to plan, implement, monitor and configure individual manufacturing processes as well as entire process chains quickly and cost-effectively. Efficient networks allow the provision

of flexible and easily adjustable systems for all stages of the customized production cycle, from the drawing board to the recycling facility.

With their comprehensive technological knowledge and understanding of individual processes as well as integrated process chains in the pilot lines, the three Fraunhofer Institutes can deliver nearly complete virtual representations of each process and processing status anywhere along the production chain. The Smart Manufacturing Network stores a digital twin for every individual component, making these twins available for all systems.

The ICNAP ultimately aims to use suitable data architectures, big data into smart data tools and cloud services to convert this detailed and integrated representation of the process into concrete technological applications.





5G DATA TRANSMISSION IN PRODUCTION SYSTEMS

Most discussions about Industrie 4.0 tacitly assume that any such system will involve the processing and evaluation of large data volumes. But while modern sensor technology may already be capable of collecting a wide range of machine and production data, it is proving more difficult to analyze this information comprehensively in a single data control center and to feed the results quickly back into an optimized production cycle. This is why the conversion to flexible and adaptive manufacturing processes requires fast, reliable and (preferably) wireless data transmission systems.

The forthcoming 5G mobile communications standard appears to be the perfect fit for the complex measuring and control technologies of networked adaptive production lines, providing short latencies (of less than one millisecond), high data transmission rates (up to 10,000 Megabits per second) and the possibility of operating many devices simultaneously in narrowly restricted radio cells.

In close cooperation with the Swedish mobile communications provider Ericsson, we are developing and testing scenarios for the industrial application of 5G in realistic production environments.

5G – Robustness and real-time capabilities for networked adaptive production processes

The operation of high-precision machine tools in complex production processes requires stable and reliable communication systems. 5G technology is making it possible to introduce wireless sensor technology into industrial environments on a grand scale, paving the way for real-time data analyses and adaptive manufacturing control systems with short response times.

Ericsson – one of our partners in the ICNAP – plays a leading role in the development of the 5G standard and 5G products. It is our common objective to test the technology with the explicit aim to apply it in industrial environments and to develop it further for a range of individual applications that require the integration of machines, production systems, data transmission systems and databases into networks of mutual communication.

Ultimately, we regard it as our mission to enable our partners in the ICNAP who are helping us to pioneer machine-integrated 5G data transmission to manufacture customized versions or small series of technologically sophisticated products more flexibly, more efficiently and at a lower cost.

Fraunhofer at Aachen

International Center for Networked, Adaptive Production

Karl Lossie
Community Manager
c/o Fraunhofer Institute for Production Technology IPT
Steinbachstrasse 17
52074 Aachen
Germany
Phone +49 241 8904-299
community@icnap.de

Fraunhofer Institute for Production Technology IPT

Mario Pothen
Phone +49 241 8904-144
mario.pothen@ipt.fraunhofer.de

Fraunhofer Institute for Laser Technology ILT

Dr.-Ing. Alexander Olowinsky
Phone +49 241 8906-491
alexander.olowinsky@ilt.fraunhofer.de

Fraunhofer Institute for Molecular Biology and Applied Ecology IME

Dr. rer. nat. Johannes Buyel
Phone +49 241 6085-13162
johannes.buyel@ime.fraunhofer.de

www.icnap.de/en

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