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AUTONOMIK
INDUSTRIE 4.0

AUTONOMICS for Industry 4.0

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Content

Foreword

Industrial production is one of the power fields of our economy. Ergonomically designed, quality-orientated products that meet the highest technological demands are the flagships of many industries and guarantee Germany's ability to compete on an international scale. In recent decades, our country's manufacturing industry has repeatedly responded to technological and economic challenges with sustainable regeneration processes. This is also what I hope to see for the transformation of industrial production that will be brought about by the advent of digital technologies, i.e. the age of Industry 4.0.

The importance of industrial production is growing once again in many countries. Today's advanced production methods are bringing production closer to the customer. Low wages are no longer the crucial factor. Industry 4.0, the so-called fourth industrial revolution, is about flexible, timely and eco-friendly production according to customer requests. Other nations have also recognised this potential and have invested considerable effort in re-industrialisation so that competitive pressure will continue to rise.

One of the major challenges for Germany in implementing Industry 4.0 is interaction between different disciplines. The entire technological know-how from mechanical engineering and plant construction, from automation technology, logistics, electrical engineering as well as information and communication technologies now has to be bundled. Common language levels will have to be found and cross-industry integration processes quickly introduced. Our aim is to set internationally accepted standards for production from our position here in Germany. In the field of information and communication technologies, in particular, this is an opportunity for Germany to regain lost ground in the further development of important web technologies and to take a leading role where future industrial requirements are concerned.

Industry 4.0 will be one of the focus areas of the Digital Agenda for Germany. Top of the list here are the digitisation of traditional industries and their expansion to include smart services. Our new technology programme AUTONOMIK für Industrie 4.0 (in English: AUTONOMICS for Industry 4.0) will bring together around 100 highly recognised partners from academia and industry in 14 collaborative projects that will outline the feasibility, potential and economic benefits of networked, smart production in the future.

Industrial IT security is one of the major challenges posed by Industry 4.0 and a precondition for acceptance and trust at the customer end. New questions are emerging regarding legal certainty where data protection and product liability are concerned and the future of work, especially with a view to industrial safety and qualifications. What's important for me is that the fourth industrial revolution should not lead to factories deserted of people. This does not have to be the case. Industry 4.0 is opening up new possibilities for employees. It calls for more workers and workers with other skills. Scientific assistance for "AUTONOMIK für Industrie 4.0" together with experts from the projects and the participating sectors will develop solutions and recommendations for action for this and other important cross-cutting topics.

I am confident that the German economy will successfully master the challenge that is Industry 4.0.

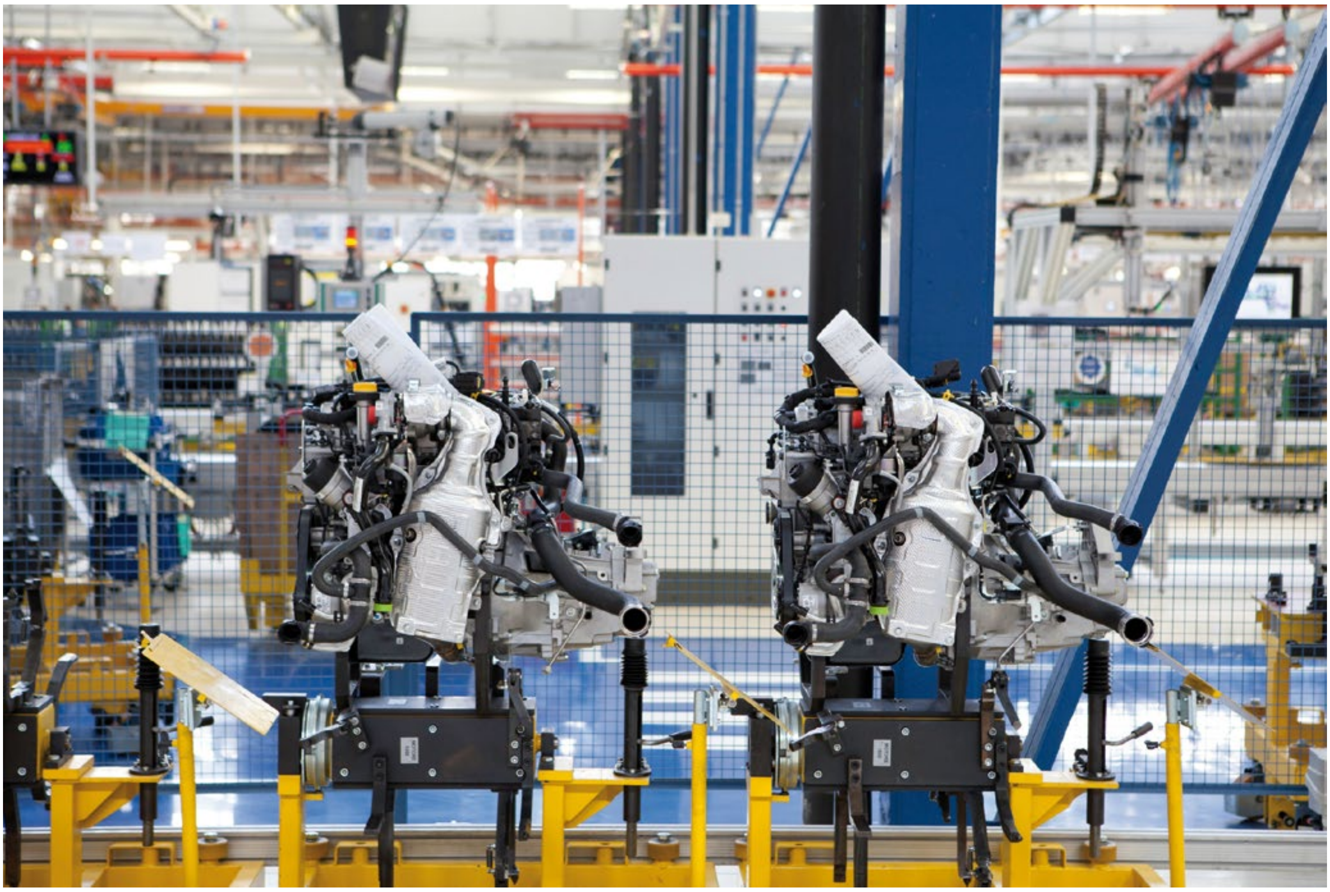
Your

“AUTONOMIK für Industrie 4.0”

In recent years, the Internet of Things has reached a high level of technological maturity and is now the driving force behind important developments in many user sectors. In an industrial context, the term “Industry 4.0” refers to the link between the digital world of the Internet and conventional processes and services in manufacturing. There are high expectations for this development. Many expect that the fourth industrial revolution will bring with it huge opportunities for the economy while at the same time posing considerable challenges for all stakeholders, but that it will also mean massive upheaval in some areas. For Germany, it is important that this development be used to improve its advantage as a centre of industry. As part of the Digital Agenda for Germany, the Federal Ministry for Economic Affairs and Energy with its technology programme “AUTONOMIK für Industrie 4.0” is going to great lengths to implement the “Industry 4.0 Future Project”. The ambitious political goal of Industry 4.0 is to establish Germany in its capacity as a supplier and user of new and trailblazing Internet-based technologies for industrial production as a lead market for both suppliers and users.

With its focus on digitising manufacturing in Germany, the “AUTONOMIK für Industrie 4.0” technology programme is embedded in a determined and lasting sequence of support initiatives designed to exploit the technological and economic potential of the Internet of Things. The technology programmes “Next Generation Media – networking living and working environments” (2006 – 2010) and “AUTONOMIK für Industrie 4.0 ” (2010 – 2013) are among the forerunners.

The purpose of the digitisation aimed for in manufacturing is to create highly flexible production infrastructures in order to meet growing demand for more customised products and to further increase efficiency and quality, as well as eco-friendly production processes. The foundation for this are machines and components that are embedded with computing power and software intelligence (embedded systems, embedded software) to form so-called cyber-physical systems (CPSs), providing them with new abilities, i.e. to communicate over the Internet, act autonomously and to interact intelligently with people and other machines. This is opening up completely new possibilities for designing entire production networks with



a distributed organisation that can transcend company and national borders. It is not just production itself that will be affected by this paradigm shift: At the production end, the focus is on new methods for customer-innovated design of products combined with early statements regarding feasibility and costs. The exploitation of new added value potential and business models will also result from the connection of production networks and products (hybrid products) with knowledge-intensive smart services.

The collaborative projects funded under this programme were selected in an open technology competition with the support of an expert committee with considerable professional expertise. All in all, around one hundred high-profile partners from academia and industry are working hand in hand in the collaborative projects in order to outline the feasibility, potential and economic benefits of networked, smart production in the future.

In the fields of production, logistics, robotics and services, the projects selected are focusing on the following topics:

- Mobile assistance systems and Internet services in smart production
- Plug-and-play networking of machines and systems
- Autonomous, driverless transport vehicles
- Bionically controlled production systems for manufacturing customised products
- Protection and safety concepts for co-operation between humans and robots in joint working areas
- Stock-taking in warehouses with autonomous flying robots
- Planning and decision support systems for selecting industrial service robots
- Autonomous realtime assistance for workers in production
- A 3D-supported engineering platform for intuitive development and efficient commissioning of production plants
- Plug-and-play integration of robots into industrial automation
- Distributed production control for the automotive industry
- Autonomous and networked construction machines in road construction
- Automated custom manufacture of sports shoes and textiles
- Template-based development of business models for Industry 4.0 with IT tool support for developing and operationalising new business fields

The recommendations for implementing Industry 4.0[1] are an important point of reference for the innovation projects. These recommendations were derived from an analysis of both technological and non-technological fields of action which are considered to be essential for the successful implementation of the Industry 4.0 scenario. Coming from a single-company perspective and the specific challenges facing the projects, needs will arise and findings gathered which will be addressed in close co-operation with the established working groups of the "Industry 4.0 Platform". The extensive exchange of information and experience will be promoted by scientific assistance for the "AUTONOMIK für Industrie 4.0" technology programme commissioned by the Federal Ministry for Economic Affairs and Energy.

Tasks of scientific assistance and the project sponsors

1 Industrie 4.0 Working Group (Forschungsunion, acatech): Recommendations for implementing the strategic initiative Industrie 4.0, April 2013

Fields of action in the „Industry 4.0 Future Project"

- **Safety and security** as a success factor
- **Regulatory** framework
- **Work organisation** and **design** in the digital industrial age
- **Standardisation** and **open standards** for a reference architecture
- Mastering **complex systems**
- Comprehensive **broadband infrastructure** for industry
- **Training and continuing professional development**
- **Resource efficiency**
- **New business models**

Source: Industrie 4.0 Working Group (Forschungsunion, acatech): Recommendations for implementing the strategic initiative Industrie 4.0, April 2013

The projects supported under the "AUTONOMIK für Industrie 4.0" technology programme are backed by project sponsor "DLR Project Management Agency, IT/Electromobility Dept." of the Federal Ministry for Economic Affairs and Energy at the German Aerospace Centre (DLR) and additionally by scientific assistance of VDI/VDE Innovation + Technik GmbH commissioned by the Federal Ministry for Economic Affairs and Energy. The aim is to warrant a high degree of efficiency for the support measures as well as high quality project outcomes. Furthermore, the support measures should go a long way towards boosting the benefits of the overall programme beyond the scope of individual projects. The findings should be made available to interested parties and other application areas in order to ensure maximum use of funds. The project sponsor at the German Aerospace Centre (DLR) is the central stakeholder for project support in conjunction with "AUTONOMIK für Industrie 4.0". It prepares the support measures on behalf of the Federal Ministry for Economic Affairs and Energy and accompanies projects during preparation and implementation with professional and administrative support based on the applicable promotion regulations.

The additional tasks of scientific assistance include:

- Ongoing analysis of the progress and alignment of the supported projects in the context of international developments in technology and changing market conditions. Based on this, findings and recommendations will be derived for the necessary adjustments and passed on to the project stakeholders.
- Support for the projects during the sustainable exploitation of the project results and their transfer to feasible business models.[2]
- Initiation of suitable networks to stimulate the transfer of knowledge and collaboration across projects and programmes in order to generate synergies. This refers especially to networking among the collaborative projects and with external partners (including initiatives, such as the Industry 4.0 Platform and comparable projects, also at EU level).

2 See also the GEMINI project; the process and outcomes of this project are used and referred to here.

- Identification and preparation of relevant cross-project issues and challenges, such as regulatory aspects, standardisation, industrial IT security and changes in the working world.
- Analyses and brief studies, for instance, on the technological and economic potential of cyber-physical systems in logistics and production, on the transfer of findings in automation technology to industrial service robotics and on other relevant issues from the projects.
- Deriving knowledge that can be generalised as well as preparation and processing for specific target groups (guidelines, good-practice brochures, etc.).
- Co-ordinating, combining and supporting publicity measures for the technology projects funded in order to achieve a uniform image and recognition of the overall programme.
- Hosting of workshops and conferences to disseminate results. Support during trade fair participation by the projects funded.
- Professional management and editing of the Internet platform.

Cross-cutting topics of particular relevance

The topics related to the action fields of the Industry 4.0 Future Project will be looked at more closely as part of scientific assistance:

- **Legal challenges**
  Findings related to the safe use of autonomous systems in compliance with law, liability under civil and criminal law, issues regarding operating permits and certification as well as risk management, industrial safety and data protection were already addressed in the Autonomics technology programme. These findings are to be mirrored in the challenges facing the current collaborative

projects of the "AUTONOMIK für Industrie 4.0" technology programme where they will undergo specific further development and then be formulated as outcomes in order to provide all stakeholders with legal certainty and orientation.

- **Standardisation**
  Standards are the foundation for the efficiency and effectiveness of highly networked systems in Industry 4.0. Scientific assistance considers standardisation at project level during development, involvement in a reference architecture for cyber-physical systems in Industry 4.0 and the further development of the national standards roadmap based on the needs of the projects (bottom-up) to be an essential part of strengthening the competitiveness of the collaborative projects, in particular, and German industry, in general. Scientific assistance is hence in a position to contribute and represent the interests of AUTONOMIK für Industrie 4.0 projects in established standardisation committees on Industry 4.0. This scientific assistance will also explore and make use of possibilities to actively accompany this important topic, at least at European level.

- **IT security for Industry 4.0**
  Protecting the IT-based infrastructure of networked machines and systems for automation, as well as monitoring and control of industrial processes are enormous challenges facing companies. In addition to data protection, customers and partners rightly expect the highest degree of protection against any possible attacks, such as espionage and sabotage. As processes in production, logistics and hybrid services transcend corporate and national borders, systems become more complex and susceptible to attack. In close co-operation with experts for industrial IT security, scientific assistance will organise and evaluate platforms to discuss solutions based on existing practices and mechanisms as well as security-by-design approaches and security architectures designed to meet the new qualities of Industry 4.0.

- **The future of work in Industry 4.0**
  Man-machine interaction in autonomous technical systems and processes in Industry will bring with it both risks and opportunities. Driverless, gesture-responsive transport systems, co-operating, assisting robots and autonomous cyber-physical systems are posing new challenges for work design and organisation. This means that the quality of work, including factors such as work satisfaction, the promotion of learning and health, may undergo significant change. Based on the experience gained in the expired Autonomics technology programme, which is documented in a comprehensive publication, different „futures" and design options will be discussed in order to make heard the justified interests of employees and companies regarding work in Industry 4.0 and to work on jointly identified objectives.

- **Business models for Industry 4.0**
  The Industry 4.0 paradigm will confront companies with fundamental change in the nature of their value streams. In future, companies will network their systems, machines, components, logistics and operating equipment. Thanks to state-of-the-art IT, it will be possible for the machines and components themselves to actively support the production process. For established companies, the transformation from a pure manufacturing company to a service provider will open up new business fields, for instance, by offering related services from one source.

APPsist

Mobile assistance systems and Internet services in smart production

Brief description

The APPsist project is developing a holistic approach for man-machine interaction in production. Based on the specific expertise of employees, software-based assistance systems will automatically adapt to meet their support needs. In this way, support and learning processes can be developed to meet very different needs, such as commissioning, operation, maintenance, repair and preventive servicing of systems. With made-to-measure support like this, employees with different levels of knowledge can be assigned a wider range of tasks than before.

The challenge

Customers today often demand bespoke product variants combined with high product quality and the low price customary in series production. In an effort to meet these demands, manufacturing companies are increasingly relying on production systems that are both highly automated and flexible. But as such production systems become more complex and their individual components become "smarter", the demands placed on employees in production are also growing, for instance, with a view to commissioning, monitoring, maintenance and servicing. In addition to assembly skills, employees now also have to be proficient in electronics and data technology.

Aim

hat's why multi-medial "assistance systems" are being developed in the APPsist project to support workers to use cyber-physical systems in production and exchange knowledge with each other. These assistance services are to take into account the qualifications and knowledge of the respective employee together with the given circumstances of the specific work situation in which the employee interacts with a component in the production system.

Technologies

The researchers are employing AI, knowledge management and semantic technology methods so that the digital assistant can give the right answers no matter what the situation. Virtual-reality and augmented-reality technologies are also to be tested, for instance, in order to simulate a production process. In this case, the user wears data glasses which display, for instance, the correct wiring of electronic components. In addition to these technically orientated tasks, the project also addresses matters of work organisation and economics which can arise when this new generation of assistance systems is launched along with the related changes in organisational structures and processes. From the very beginning, employees, works councils and the IG Metall union will be involved in the design and shaping of the system. The project is also to examine the extent to which it makes sense to integrate gamification, i.e. gaming elements and incentives, into industrial assistance systems in order to boost job satisfaction and motivation. The functions of the APPsist system are to be made available via a company cloud.

Use Case

The APPsist assistance systems will be tested at three project partners working in the production sector: toolmaker Brabant & Lehnert, automation technology supplier Festo and plant construction company MBB Fertigungstechnik. Production staff working in the pilot applications will be offered a host of digital assistance services. This support ranges from operating instructions for the next work steps to an "emergency service", right through to options for discussing technical matters with other colleagues in a fast and simple manner. Touchscreens on the machines or apps on smart phones, tablets and PCs will provide fast access to the services.

Partners

Festo Lernzentrum Saar GmbH (consortium leader), Brabant & Lehnert GmbH, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH (DFKI), Festo AG, Fraunhofer IAO, imc information multimedia communication AG, MBB Fertigungstechnik GmbH, Ruhr-Universität Bochum

Contact

Klaus Herrmann (herm@de.festo.com)
Festo Lernzentrum Saar GmbH

www.appsist.de

Innovations with APPsist

Up to now	With APPsist
Partial support for workers during individual work tasks, e.g. assembly instructions.	Inclusion of all work processes of a production line or machine, including commissioning, production, monitoring and maintenance.
Identification of knowledge gaps and skills among production workers and addressing these through courses and training.	Systematic recording of worker competence profiles and automatic alignment of assistance services to the knowledge and skills of workers.
Hardly any feasible approaches for marketing the services of cyber-physical systems.	Using application scenarios, specific business models for Appsist services are outlined and tested.
The introduction of innovative rationalisation technologies is often met by reservations among workers.	Project work is carried out in dialogue with workers, the application pilots and their representatives.

CoCoS

Plug-and-play networking in production

Brief description

CoCoS is developing a smart information and communication infrastructure with the ability to both recognise the different components of a production line, such as machines and workpieces, and to network them with each other. It is also designed to form a communication bridge between the production, logistics and other management systems used that could then be designed as a distributed and virtual bridge. Separate networking of independent production systems at different locations is also to be made possible. No in-depth skills will be required, neither for commissioning the production line nor for any necessary adjustments.

The challenge

The transformation of the world of production has already begun: Consumer and investment goods are becoming more complex and varied, their production cycles narrower and the time between development and market launch shorter. It is almost impossible for today's production systems to keep pace with this. Their components can rarely be reconfigured, they are rigidly interconnected and controlled strictly according to hierarchies. Up to now, networking across different production sites has been very complicated.

Target

This aim of the CoCoS project is therefore to develop an information and communication platform that will remove these barriers. This will begin with the machines, transport equipment and workpieces in a production line which will be networked using sensors, actuators, software and communication systems. The CoCoS platform will connect these systems to form a smart, networked production system. In this way, production at suppliers and producers will be included across different operating facilities and logistics service providers integrated. Despite all of this, it will be possible to adapt the system quickly and easily to new production processes.

Technologies

The CoCoS platform will feature several levels (multi-layer approach). The lowest level, the "physical networking platform" connects the components of a production line to form a communication network. It integrates the customary networks and communication equipment in production, such as wifi, industrial ethernet or RFID, and supplements network management methods which have not been widely used up to now in production networks: self-configuration, self-optimisation, self-healing, anomaly detection, virtualisation and mature security management. CoCoS will also integrate wireless sensor networks. In order to efficiently process the huge quantity of sensor data expected, in-network data processing methods will be tested in the project where simple calculations can already be carried out in the network in order to lessen the load for the central components.

The "services platform" is the next level after this communication base. This is where all components of the cyber-physical production system, whether machine, workpiece or transport system, are first described in a uniform manner as information objects with dedicated data and services, for instance, for status monitoring. An innovative runtime environment enables the implementation and use of added-value services, for instance, for production planning or control. From a user perspective, the production system is now a collection of information objects on one service platform and the user can use these (virtual) services via apps on a smart phone, tablet or PC and combine them to create new production workflows. CoCoS hence provides the user with a production control system that allows him to install, monitor, maintain, control and reconfigure production processes.

The various production systems will be connected across production sites and company borders using the Virtual Fort Knox (VFK) cloud infrastructure from Stuttgart-based Fraunhofer Institute for Manufacturing Engineering and Automation. Thanks to VFK, IT services can be made available to the production sector in a simple, flexible and secure manner.

Use Case

CoCoS will be tested in a cross-company demonstrator. For the production of plug connectors or housings, for instance, at Bosch in Schwieberdingen, the DFKI Smart Factory in Kaiserslautern as a supplier and machines for parts production at DMG Electronics in Pfronten will be connected to each other via the VFK cloud.

Partners
Robert Bosch GmbH (consortium leader), Deutsches Forschungszentrum für Künstliche Intelligenz GmbH (DFKI), DMG Electronics GmbH, trustsec IT-solutions GmbH, TU Berlin, XETICS GmbH

Contact
Dr. Patrick Nickel (Patrick.Nickel@de.bosch.com)
Robert Bosch GmbH

www.cocos-project.de

Innovations with CoCoS

Up to now	With CoCoS
Due to heterogenous technologies and network protocols in IT networks, direct communication between components is often not possible or at least requires using dedicated software systems. This leads to long runtimes for messages and the need for considerable integration effort.	The components of a production line are connected to one communication network.
High-quality management functions, such as self-configuration, self-optimisation, self-healing (self-x), anomaly detection, virtualisation and mature security management are seldom found in today's production networks.	Self-x and virtualisation functions are transmitted on IT networks in production and enable much simpler administration and expansion of networks.
The transport and evaluation of large quantities of sensor data burden wireless sensor networks that already have to contend with longer load times and failure rates.	The concept of in-network data processing significantly lessens the burden on central nodes in sensor networks. This reduces the runtime of messages while the number of communication failures is also reduced.
Components in today's production systems usually have simple programmable logic controllers and only very few interfaces for external systems. This means that commissioning, reconfiguration and integration into higher-level control systems is very difficult.	All important data and functions of a component are offered in standard form as a service on a service platform. The integration of components into a production system or the implementation of new control and management functions is hence achieved by combining services to form new services via an easy-to-use graphic user interface („orchestration").
No comprehensive technical solution for simple, low-cost and secure networking of production systems across several sites and companies.	Production systems can be easily connected to each other across several operating sites both with a view to network communication and also at production process level.

FTF out of the box

Autonomous, driverless transport vehicles with voice and gesture control

Brief description

FTF out of the box is developing smart, driverless transport vehicles which, after delivery and one introductory trip controlled by an operator, can find their way in the factory hall, remember their surroundings and can be assigned transport jobs, for instance, simply using voice and gesture commands. Previous systems involved long and difficult learning and reconfiguration phases, such as the prior implementation of a location map or the installation of artificial landmarks. Significant savings are now possible for customers.

The challenge

Driverless transport vehicles can boost the efficiency of logistics processes considerably compared to the manual transport of goods. The solutions currently in place are either partially autonomous, i.e. pick-up and drop-down are still manually controlled by the user, or fully automated which means that special, complicated software solutions are needed for control. The operation of partially autonomous systems is still not very intuitive and staff need to be specially qualified. When autonomous systems are used, warehouse infrastructures have to undergo far-reaching, costly modification in order to enable reliable navigation. Today's autonomous systems also lack flexibility when it comes to adapting to changed environments. If an obstacle appears, an emergency stop is triggered in the vehicles. Goods that are not at the expected location usually cannot be picked up. There is hence considerable demand for adaptive and easy-to-use driverless transport vehicles with low installation requirements.

Aim

In the FTF out of the box project, driverless transport vehicle concepts are being transferred to autonomous fork-lift trucks and developed further. The aim is for the fork-lift trucks to be able to find their own way in warehouses, to remember their surroundings, to find their way on the basis of landmarks and to respond adaptively to changes. Furthermore, warehouse staff can easily assign jobs to them using voice and gesture commands.

Technologies

Innovative 3D cameras and smart image processing software ensure that the vehicle itself can scan its surroundings, store a type of map and then find its way about by itself. The system is continuously learning and recognises when the warehouse has been cleared or if the surroundings have changed. What's more, obstacles and people are reliably recognised and safely avoided. All obstacles are captured throughout by cameras that can also be used for other purposes, such as object identification or automatic documentation of logistics processes. This concept reduces installation and equipment costs as well as operating complexity. The innovative optics used also enables gesture control so that all the user has to do is point to the pallet which the vehicle is to move. Or, the next job can be assigned to the vehicle using a voice command. Thanks to gesture and voice-based interaction, the system can be intuitively operated without the need for specially developed interfaces or interfaces with the warehouse management system. Special skills to control the vehicles are also no longer needed. Thanks to the system's technical design, no structural changes are necessary to allow the system to find, making driverless transport systems an economically viable solution even for smaller companies.

Use Case

FTF out of the box in the automotive, aviation, foods and haulage sector will demonstrate in practical application that driverless transport systems can autonomously localise, pick up and drop down transport goods and move them reliably to the destination. Thanks to simple operation, a single warehouse worker is to be able to control several vehicles at the same time.

Partners

Jungheinrich AG (consortium leader), Basler AG, Götting KG, Universität zu Lübeck, IPH – Institut für Integrierte Produktion Hannover gGmbH

Contact

Dr. Frank Mänken (frank.maenken@jungheinrich.de)
Jungheinrich AG

www.ftf-out-of-the-box.de

Innovations with FTF out of the box

Up to now	With FTF out of the box
Conventional FTF solutions usually use dedicated special laser scanners to detect obstacles.	Obstacles are detected throughout by cameras that can also be used for other purposes, such as object identification or automatic documentation. This reduces both device costs and operating complexity.
Visual assistance systems for placement and removal of pallets using a forklift use 2D cameras. Due to the lack of 3D information, these processes cannot be automated.	One camera that supplies both 2D images and 3D information boosts the assistance function and allows automated placement and removal of pallets, even in areas that are difficult to see.
In addition to supplying 3D information, today's 3D cameras supply only 2D images in grey shades. This means that special, high-contrast markings are needed for navigation control.	New camera systems enable the combined display of 3D information and 2D images in colour. This increases the range of potential markings in the environment for navigation control.
Extremely sensitive sensor systems are currently required for autonomous creation of maps in unknown environments and independent localisation of transport vehicles on these maps.	Using 3D camera systems, artificial markings, global positioning systems and expensive laser scanners are no longer needed. This means that the systems can be easily integrated into legacy infrastructures.
Driverless transport vehicles are co-ordinated via a main control centre from where each vehicle receives its jobs or is controlled via special interfaces, such as tablets or smartphones.	In addition to voice-based interaction, gesture-based interaction using 3D cameras enables order placement directly on site in the logistics hall without the need for specially developed interfaces in the control centres. This natural interaction means that special skills in vehicle control are no longer needed.
In the case of semi-automated systems, the transport pallets are currently placed and removed manually. Autonomous forklifts are controlled by a single software system which requires complex interfaces with the warehouse management systems.	The employee becomes the interface between warehouse management and the forklifts which place and remove pallets autonomously. Special software developments are no longer necessary and thanks to the simple voice and gesture-based operating concept a single warehouse worker can control an entire fleet of forklifts at the same time.

GEMINI

Business models for Industry 4.0

Brief description

The aim of the GEMINI project is to develop feasible business models within the context of Industry 4.0. The instrument being created by GEMINI enables the participating companies and organisations to develop and implement individual business models by providing them with methods, processes and IT tools.

The challenge

The Industry 4.0 paradigm has resulted in manufacturing companies having to face fundamental change in the nature of their value streams. The possibilities offered by Industry 4.0 will result in opportunities for completely new business models. However, it is difficult for companies to review both the fascinating opportunities and the risks of Industry 4.0 and to develop innovative business models. There is a need for support when it comes to the developing and assessing the risks of and implementing innovative business models for Industry 4.0. The aim of the GEMINI project is to create instruments to develop and implement viable business models based on the opportunities available within the context of Industry 4.0.

Technologies

The participating companies and organisations will be provided with an instrument that enables them to develop and effectively operate individual business models. Starting with a business idea, general business model patterns and those specific to Industry 4.0 will be identified (e.g. remote maintenance, digitisation, customised mass production). These patterns will be stored in a knowledge base and combined to form promising business models. This pattern-based approach makes it easier to develop business models and enables efficient estimation and minimisation of possible risks. An operationalisation planner ensures that the business model developed is integrated into the company's value stream. Moreover, a business model converter on the online platform (www.innovations-wissen.de) will help potential users to create business models. These scientifically based methods will be validated in pilot projects on the basis of specific examples. The experience and findings won will be fed into the knowledge base and the toolkit.

Use Case

The different focus areas of business model development will be examined further in five pilot projects. Additive manufacturing (AM) enables tool-free manufacturing of customised components directly from CAD models. A B2B platform assigns this CAD data and the corresponding assembly jobs in a network of distributed AM machines. Other pilot projects will deal with cloud-based services for Industry 4.0 and a platform for integrated production networks. Unique new business models are also being developed for three selected projects from the "AUTONOMIK für Industrie 4.0" support programme. The focus is on networking and services infrastructures for cyber-physical production systems (CoCoS), reusable smart services for flexible robot systems (ReApp) and systems for automated localisation and inventory management of warehouse stocks using autonomous flying robots (InventAIRy).

Partners
Universität Paderborn (consortium leader), Atos IT Solutions and Services GmbH, CONTACT Software GmbH, Fraunhofer IPT, Ruhr-Universität Bochum, SLM Solutions Group AG, UNITY AG

Contact
Prof. Dr. Ing. Jürgen Gausemeier
Stefan Peter (stefan.peter@hni.uni-paderborn.de)
Universität Paderborn

www.geschaeftsmodelle-i40.de

Innovations with GEMINI

Up to now	With GEMINI
There is no methodological support available for developing new business models in the context of Industry 4.0.	A systematic approach supports the development of business models based on Industry 4.0 ideas.
Innovative Industry 4.0 business models are frequently based on Industry 4.0 technologies as well as generally successful and widely known business model templates.	GEMINI provides a catalogue of business model templates specific to Industry 4.0.
There has been hardly any research into the impact of new Industry 4.0 business models on the distribution of risks among stakeholders in the value chain.	One method of risk evaluation takes into account the different risks borne by all stakeholders in a value chain.
There is still no integrative assessment of the value system and business model in the context of Industry 4.0.	An approach model and a library with standard versions of value-added networks enable companies to move from the business model to a viable value system.
There is no comprehensive tool support available for developing and operationalising Industry 4.0 business models.	An integrated IT tool supports users from the business idea to implementation of a business model in the context of Industry 4.0.

InnoCyFer

Bionically controlled production systems for manufacturing customised products

Brief description

The InnoCyFer project is developing a web-based open-innovation platform. This platform will provide customers with a toolkit that allows them to design products, within the scope of what is technically feasible, individually and according to their own ideas without the need for specific skills. Unique new autonomous production planning and control methods will be developed to manufacture these custom-innovated products. The methods will be based on flexible and adaptive forms of organisation found in biology. In this way, jobs can be planned at short notice and requests for changes can be permitted at late phases in the production process.

The challenge

It is becoming increasingly possible for consumers to have their design requests implemented. For instance, when it comes to configuring a new car, it is now possible to adapt the product within precisely defined limits to one's own wishes and ideas. More and more customers, however, are calling for an even greater degree of customisation. They want to directly influence the design and function of the product. However, this requires new infrastructures and extremely flexible production lines that allow customer wishes to be implemented at short notice and enable changes to be permitted at very late phases of the product development process.

Aim

As part of the InnoCyFer project, an open-innovation platform is to be developed that will allow the creative and innovative potential of customers to be integrated into the product development process. The platform will be networked with a new type of planning and control for an autonomous manufacturing system. This will make highly customised and flexible production possible along with a high number of variants and low quantities. The innovation potential of customers can also be used by manufacturers to develop new products and designs.

Technologies

Using a web-based, open-innovation platform, customers can create a completely new design or adapt existing designs to their own wishes or ideas. The customised designs can then be published on the open-innovation platform in order to receive other ideas, solutions to problems or opinions from other customers. The manufacturer also informs the customer via the open-innovation platform as to whether the customised product is actually feasible, the expected delivery period and the cost of the product.

One special feature of bionic production control is that the manufacturing system flexibly adapts to the respective customer jobs without any interruption in operations. The customer can modify, in as far as possible and at short notice, jobs already initiated right up into late production phases. This is to be made possible by "bionic production control" within the entire value chain which will ensure a high degree of flexibility and simple intervention combined with low error tolerance and a low degree of complexity. Nature serves as the model here, for instance, where ants, without central control, collectively master complex tasks by marking scent trails. This kind of self-control is now to be used in industry so that production lines can be decentrally organised and scalable as required. Machines, parts, products, workers, planning and control components are the individual "ants" which communicate with each other via "digital scent trails". Depending on the exterior conditions (customer requests, material stocks, machine utilisation and availability, suppliers, job priority), the overall system continuously reorganises without the need for a central planning authority – just like the ant colony.

Use Case

The example of a customised coffee machine is used to demonstrate the path from the standardised to the customised products.

Partners
TU München (consortium leader), BSH Hausgeräte GmbH, Festo Didactic GmbH & Co. KG, Fraunhofer IWU – Projektgruppe RMV, HYVE Innovation Community GmbH

Contact
Michael Niehues (Michael.Niehues@iwb.tum.de)
Technische Universität München

www.innocyfer.de

Innovations with InnoCyFer

Up to now	With InnoCyFer
Customers can intervene in the final design of their product either only before or after production (material selection, finishing, etc.).	Thanks to close interaction between production planning and control and the open-innovation platform, changes are still possible at a late stage of product creation. The customer also receives feedback at any time regarding whether the requests made are possible and whether changes in deadline and costs are to be expected.
Individual product requests by customers can only be considered in pre-defined variants.	Even complex technical products can be freely and individually designed by the customer using the open-innovation platform.
Due to rigid production control, any scaling of production control in the event of unexpectedly high demand calls for complicated intervention.	Bionic production control enables fast, autonomous adaptation of the production process to external and internal changes.
Customized production is based on a direct relationship between the customer (perhaps an intermediary) and the manufacturer.	In addition to exchange between the customer and manufacturer, customers also communicate with each other via the open-innovation platform. In a community like this, customers can benefit from the knowledge and experience of other customers.
Manufacturers have very few possibilities to benefit from the creative and innovative potential of their customers.	The collective intelligence of a large customer base (open innovation) can help the manufacturer to develop new designs and enhance the product portfolio without having to invest heavily in research and development.

InSA

Protection and safety concepts for co-operation between humans and robots in joint working areas

Brief description

In the InSA project, previously independent working areas of employees in production and of robot systems are monitored using sensor technology in order to co-ordinate safety precautions. The system records current activities and, taking the context and respective situation into account, assesses the risk potential which a worker, for instance, could be exposed to due to robot movements. The aim of this project is technical standardisation of these context-orientated production systems and their integration into smart production environments, so that the economic efficiency of industrial robots can be improved in mixed working environments.

The challenge

Robots and people will work closely together in the factory of tomorrow. Up to now, robotic and human workplaces have been strictly separated for safety reasons, for instance, using safety fences. However, if they were to co-operate closely this would promote efficient and smooth production. And when man and machine work together today, the robot stops immediately as soon as a dangerous situation is detected. The consequence of this is that production slows down or comes completely to a halt. What's needed are new protection concepts that permit close interaction by both players and keep disruptions in operations to a minimum.

Aim

As part of the InSA project, researchers are working on a comprehensive protection model that includes the user of a robot and his context, his environment, his activities and interaction. The system records current activities and, taking the context and respective situation into account, assesses the risk potential which a worker, for instance, could be exposed to due to robot movements. The aim of this project is technical standardisation of these context-orientated production systems and their integration into smart production environments, so that the economic efficiency of industrial robots can be improved in mixed working environments.

Technologies

This is being made possible by smart interaction between different sensor systems (magnetic field sensors, stereo cameras, laser scanners, RFID, touch sensors). The worker is fitted here with special sensor clothing and detected in the room by stereo cameras and laser scanners. Using this information, the system calculates the risks and triggers protective measures, for instance, by causing a heavy robot arm to retract when a worker is located dangerously close to the robot. Similarly, tools, such as welding devices, are used differently by the robot, speed is controlled and movement sequences are changed in the interest of safety. The top priority here is to keep workers safe at all times. In some ways, the protection mechanisms must predict what could happen.

The project also goes beyond secure man-machine interaction and also addresses work process design and the acceptance of robots working directly with people. At the same time, standardised software architectures and existing communication and interoperability standards are to be used as far as possible in order to keep the new protection concepts as simple as possible and to integrate them into legacy systems.

Use Case

The new protection concepts will be demonstrated in two scenarios. In the first scenario, workers and robots will work closely together in assembly where the worker assembles and passes on the prefabricated parts to the robot for further assembly. In this case, the work areas of the worker and the machine overlap so that reliable protection systems are vital. The second scenario is geared to maintenance of industrial systems. In this case, the assembly worker enters the work area of industrial robots where man-robot co-operation is not normally foreseen. This results in a far greater potential for risks than the first scenario, however, these risks have a limited time span.

In order to make production as efficient as possible in both scenarios, the robot should never have to stop nor should its work be excessively restricted. This is where the worker's sensor-fitted clothing comes into its own because thanks to the sensors installed at the workplace the worker's precise movements and position can be detected. The robot responds to this information so that its colleague, the worker, is not injured.

Partners
neusta mobile solutions GmbH (consortium leader), Hubert Schmitz GmbH, ThyssenKrupp System Engineering GmbH, Universität Bremen

Contact
Prof. Dr. Michael Lawo (m.lawo@neusta.de)
neusta mobile solutions GmbH

www.insa-projekt.de

Innovations with InSA

Up to now	With InSA
Humans and robots hardly ever work together in industrial workplaces.	Precise hazard detection and a comprehensive protection concept enable co-operation between humans and robots in application areas.
Safety concepts in production and assembly are usually developed and implemented for each individual component that poses a potential risk.	Safety concepts for workers, machines, systems and processes are networked. This creates full-scale protection at the workplace.
Current protection concepts usually separate the work areas of humans and robots so that co-operation between the two is not possible.	Humans and robots will be able to work together closely yet more safely.
In areas where humans and robots already meet in the factory, protective mechanisms prevent operations when risks occur because robots then have to slow down or be switched off.	Potential risks are detected very early. This means that suitable protection mechanisms can be controlled so that any restrictions to the normal workflow for the human and the machine are kept to a minimum.
Detailed detection of human behaviour at the workplace still lacks the robustness needed in an industrial setting.	The simultaneous use of different sensor systems (magnetic field sensors, stereo cameras, laser scanners, RFID, contact sensors) enables robust detection and a comprehensive protection system.
Up to now, there are only very few accredited protection measures for safe human-robot co-operation most of which are based on the use of laser scanners.	In preparation for accreditation, InSA aims to develop additional protection concepts, thus expanding the range of sensor systems available. This will open up many more application areas than before for safe human-robot co-operation.

InventAIRy

Stock-taking in warehouses with autonomous flying robots

Brief description

The aim of the InventAIRy project is to develop a system for automatic location and stock-taking of warehouse stocks using autonomous flying robots. The system sensors ensure that the flying robots can independently detect and analyse their environment so that they can navigate their way through the warehouse, detect logistics objects and do stock-taking. The system is to be used for both indoor and outdoor warehouses and easily networked with legacy warehouse management systems.

The challenge

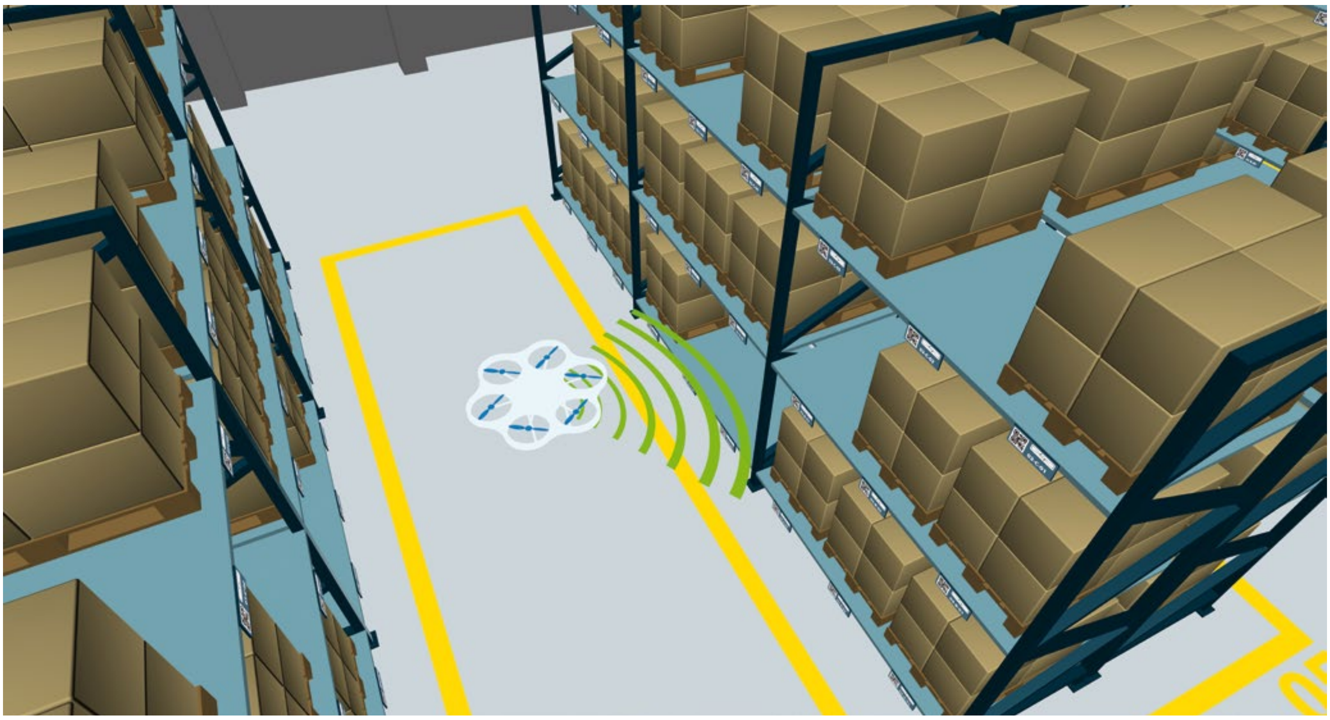
Stock-taking must be carried out in order to check warehouse stocks and comply with legal regulations. This is often a time-consuming task for part-time staff. It also uses up financial resources and can lead to errors. In addition to personnel costs, manual stock-taking also brings large parts of the warehouse to a halt. The use of bar codes and RFID chips does nothing to change this because they must also be manually scanned. The ideal solution would be to automate this error-prone process and to have it run on a continuous basis.

Aim

The aim of the InventAIRy project is to develop an autonomous flying robot which can navigate independently through the warehouse and do stock-taking thanks to the sensor systems installed. What's new is that the robot can localise objects both in warehouses and outdoors and identify them using bar codes or RFID chips. The advantage with flying robots is that they can move in all directions and even in areas that are difficult to reach, such as high-bay warehouses, irrespective of obstacles on the ground. By co-ordinating several flying robots, comprehensive material stocks can be captured very quickly. When connected to the warehouse management system, the data captured can be automatically transmitted (wireless) to higher-level software systems. This not only saves considerable time compared to conventional stock-taking, the number of errors is also drastically reduced. Another advantage is that the flying robots can continuously monitor the warehouse so that material shortages can be detected early and eliminated before they can lead to production downtimes.

Technologies

The project addresses a number of different problems: robust robot design, reliable detection of surroundings, as



well as smart software for route planning and co-ordination of flying robots. The installation of an expensive local infrastructure to provide orientation for the robots was deliberately discarded in an effort to ensure that the solution is an attractive option for small and medium-sized companies. Instead, this is made possible by smart algorithms that allow the flying robots to create fully autonomous maps of the warehouses and to independently adapt these to changes. Ultrasound sensors, 3D cameras and laser scanners will be used for this purpose. The combination is what makes it possible for the robots to perform their work reliably under difficult conditions both indoors and outdoors.

Use Case

InventAIRy will demonstrate automated inventories in the logistics areas of the automotive, spare-parts and steel industry as well as in the haulage sector. Heterogeneous warehouse structures as well as combined indoor and outdoor use are the special challenges facing this project.

Partners
Fraunhofer IML (consortium leader), Aibotix GmbH, Panopa Logistik GmbH, Rheinische Friedrich-Wilhelms-Universität Bonn, Spedition Wiedmann GmbH & Co. KG

Contact
Marco Freund (marco.freund@iml.fraunhofer.de)
Fraunhofer-Institut für Materialfluss und Logistik (IML)

www.inventairy.de

Innovations with InventAIRy

Up to now	With InventAIRy
Stock-taking is usually carried out manually and this means correspondingly high costs and inevitable documentation errors.	Once established, automated stock-taking with autonomous robots can be carried out in the long term in a cost-efficient and highly reliable manner.
Inventories are recorded at certain intervals and irregularities are often noticed too late.	InventAIRy enables continuous monitoring and stock-taking of inventories. Deviations from the desired and expected capacities can be corrected immediately.
The lack of general guidelines is currently an obstacle to the commercial use of flying robots in warehouses or production halls.	Proposals for guidelines and work rules for the use of autonomous flying robots will be made available on the basis of practical application cases and will facilitate the preparation of a legal framework.
Existing approaches for automated stock-taking usually require special infrastructures, so that warehouses enlargement requires considerable investment and additional effort. It is especially difficult for SMEs to finance a system like this.	Thanks to new object detection and localisation strategies, automated stock-taking is possible without specially installed infrastructures, even in new and expanding warehouses.
Automatically recorded inventory data requires specially developed software to integrate the data into legacy warehouse management systems.	Smart interfaces with warehouse management systems enable seamless integration of data into legacy software infrastructures without the need for custom developments.

MANUSERV

Planning and decision-making support system for selecting industrial service robots

Brief description

The MANUSERV project aims to develop a planning and decision support system that uses service robots in order to automate processes that have been carried out manually up to now. The project will examine both technical viability as well as economic feasibility. The system provides support when it comes to selecting the most suitable service robot and its programming, right through to virtual putting into operation. The solution is to be provided as a service for users via an Internet platform where suppliers will offer their service robot solutions in a technology catalogue, containing technical descriptions of the abilities of the products and robots.

The challenge

Robots are today a vital part of industrial manufacturing. But they can do so much more than handle pre-defined tasks on the spot. Robots are becoming independent and performing traditional service tasks in order to support people in their work. But the problem here is that the new technologies are finding it difficult to make their way into practical application. Even though first product approaches exist, there are in fact still only a few applications. This is because there is not a lot known about the possibilities for shifting manual processes to service robots and because there is the fear of high implementation costs. On the other hand, developers and suppliers of service robotic applications are not familiar with the manual processes that are suitable for (partial) automation. This lack of knowledge means that efficiency potential is lost, especially in small and medium-sized companies, but also in agricultural operations.

Aim

That's why a planning and decision support system is to be developed as part of the MANUSERV project. This system will help users and developers of service robotic applications to analyse and describe work process, to plan action, to select suitable service robots. The system will also provide assistance when it comes to evaluating, estimating the costs of the solution as well as implementing and programming it.

Technologies

In order to reach this goal, state-of-the-art methods in labour science are to be combined with new methods in action planning and simulation as well as robot programming. The results as well as specific planning and decision tools, for instance, a technology catalogue or an action library, will be made available to companies via an Internet portal where suppliers and users of service robotics components can meet.

Use Case

The function and advantages of MANUSERV will be tested, evaluated and optimised on the basis of three practical application scenarios. In the "Hybrid assembly with lightweight robots" application scenario, the focus is on active support for staff in the assembly of household appliances and systems rather than on full automation of a manual process. Therefore, the project work and results in this application scenario will be strongly geared to the topics of man-robot interaction and the integration of safety and monitoring systems, as well as the co-ordination of manual and automated process steps.

Another application scenario will be dedicated to autonomous equipping and maintenance of high-performance stretch-blow machines for PET bottles. What's striking about this scenario is that production is interrupted for this process. That's why service robots are to be used here to optimise maintenance, tooling or product-change times (e.g. spigot change in the heater module, mould change in the blow module).

A third application scenario will be implemented with flexible robot use in agriculture where there is a strong trend towards automation, especially when it comes to milking. But there are still many non-automated processes, for instance, cattle driving, as well as cleaning of resting cubicles and milking carousels. These processes are to be analysed as part of the project. Robotic solutions and dairy cows are not a contradiction: Cows are creatures of habit who like a regular routine. From a worker perspective, the support provided by service robots lessens the work load considerably. That's why complex and strenuous manual activities which have not been automated up to now will be transferred to robots in this project.

Partners
RIF e. V. – Institut für Forschung und Transfer (consortium leader), KHS Corpoplast GmbH, Albrecht Jung GmbH & Co. KG, GEA Farm Technologies GmbH, Icarus Consulting GmbH

Contact
Frank Heinze (Frank.Heinze@rif-ev.de)
RIF e. V. – Institut für Forschung und Transfer

www.manuserv.de

Innovations with MANUSERV

Up to now	With MANUSERV
In the field of industrial service robotics, there are already some first product approaches, however, there are still no broader applications in sight.	Solutions in industrial service robotics can be transferred to a broad range of applications.
SMEs are often not in a position to shoulder the time and money needed to plan and implement solutions for industrial service robotics.	The automated selection of suitable technologies significantly reduces the time and money needed to plan and implement industrial service robotics solutions, making this a viable option for SMEs.
It is difficult for potential suppliers and users to find Information about application scenarios and the solutions available in industrial service robotics.	Centrally stored and catalogued information about application scenarios and technical solutions can be retrieved from an Internet portal for industrial service robotics.
It is not clear which manual processes can be transferred to service robots.	Users receive from action libraries recommendations for (semi-) automation based on a manual process with a standardised description.
There are no standards for procedures and methods that provide optimum support for planning manual work steps that are to be transferred to (semi-) automated processes.	MANUSERV is based on the MTM standard for describing manual work processes (workflow-time analysis) that is expanded by automation parameters.
Testing systems solution calls for investment in hardware.	A selected system solution can be virtually put into operation without having to invest in hardware.
Comprehensive economic evaluation of service robotics solutions is not possible until after implementation, commissioning and system testing.	In addition to technological feasibility, support for planning and decision-making also includes the evaluation of economic criteria.
Programming service robots for a certain process is an obstacle, especially for SMEs.	Service robots are largely programmed in an automated process.

motionEAP

A system to boost efficiency and provide assistance in production processes

Brief description

The aim of the motionEAP project is to use motion detection and prediction as a basis for developing a system to increase efficiency and assist in production processes at companies. With cameras and distance sensors, the system detects the worker's activities and informs him of problems and potential for improvement. In addition to technical development, this product will focus on the issues of psychology and work ethics that arise from these new forms of interaction.

The challenge

Industrial suppliers have long been familiar with permanent quality control and IT-supported assistance for individual work steps. However, existing assistance systems are somewhat late to act, i.e. when the finished weld seam is checked and defects are discovered. It would be better to inform the worker while performing the task that he is about to make a mistake. Expensive rework and rejects can be avoided and worker motivation improved because the work delivered is reliably good.

Aim

Researchers in the motionEAP project are working on just such a new assistance system. Context-aware and process-integrated assistance is to be developed, i.e. the worker's work steps are analysed with the help of sensors and video so that problems or errors can be immediately identified. This could be an incorrect assembly step or even non-ergonomic posture or hand position. The system then displays a corresponding message in the worker's field of vision. motionEAP is not only conceived for fast introduction to new production workflows, it also aims to support older or impaired workers in line with their performance capabilities. The integration of game elements will also be tested in order to boost motivation and work satisfaction at the same time.

Technologies

There are a number of challenges facing the implementation of the goal: First of all, customary methods of optical movement and object detection using video cameras and 3D sensors must be adapted to the needs of production environments. In addition to body movements, facial expressions are to be analysed so that the worker's emotions can be recognised. This will especially allow error-prone stress situations to be recognised and/or avoided. However, the cameras and sensors should not hinder either the work or the material flow. Another challenge: For safety reasons, no laser projectors are to be used for display purposes in the working area, instead LED devices with weaker light are to be used which will have to be optimised accordingly.

Psychological aspects related to work and motivation are just as important as these technical matters. One central demand of this project is that the assistance system should neither overburden or underburden individual workers. During the assembly and commissioning activities supported in this way, the technical and cognitive strengths and weaknesses are to be detected by analysing motion and facial expression so that the messages from the system can be geared to the current situation. Although unnecessary errors are to be avoided, workers should not be patronised by providing too many messages. This work is based on established models of work psychology. The project also aims to examine for the first time how gaming elements and methods can be integrated into industrial assistance systems (gamification) and how they can influence work satisfaction and motivation.

Independent ethical support will ensure that aspects, such as data protection and personal autonomy and privacy at the workplace, are considered during the project.

Use Case

The motionEAP approach will be tried and tested on the basis of several application scenarios in the automotive industry and in social enterprises. The first scenario is a training and education system for assembly workplaces which uses cameras and infrared 3D sensors to capture the user's individual performance data and to gear the system to this data. In the subsequent scenarios, a projection then informs the user directly at the workplace (in-situ) of any errors. In the second scenario, the system is integrated into a production workplace where frequent product changes are also permitted. In this case, complex hand and arm movement sequences are to be detected and different styles of movement, for instance, fast hand movements, are also to be permitted. In the third scenario, components will be put together in pre-assembly. Unlike today's pick-by-light systems, the employee's attention is not only drawn to the respective pick-up spot by light signals, incorrect pick-ups are also reported. In the final scenario, several workers in an assembly cell, i.e. several assembly tables together, will be supported.

Parnters
Audi AG (consortium leader), BESSEY Tool GmbH & Co. KG, GWW GmbH, Hochschule Esslingen, KORION GmbH, Schnaithmann Maschinenbau GmbH, Universität Stuttgart

Contact
Klaus Klein (klaus.klein@audi.de)
Audi AG

www.motioneap.de

Innovations with motionEAP

Up to now	With motionEAP
Assistance systems in assembly only enable retroactive quality control of an order-picking or assembly step.	Early process-integrated detection of incorrect movements by the worker. The assistance system is "context-aware".
Usually no process-integrated feedback.	Specific, process-integrated feedback with information about the location of the error and how it can be avoided.
Assistance systems in assembly pay hardly any attention to the worker's individual skills.	The worker's technical and cognitive skills are considered individually. This means that older and impaired workers, in particular, can perform more demanding tasks in assembly than before.
Identifying the precise physical and mental load for an assembly worker is a time-consuming task.	The worker's stress level is automatically recorded and taken into account by the assistance system. Uncomfortable positions are also recognised and remedies are proposed.
Repetitive tasks in assembly can lead to fatigue and boredom and this in turn leads to additional errors.	Playful elements help to prevent fatigue and boredom, as well as stress.

OPAK

3D-supported engineering platform for intuitive development and efficient commissioning of production plants

Brief description

The OPAK project focuses on the development of a 3D-supported engineering platform for intuitive planning, development and commissioning of production plants. The plant can be initially planned, independent of the manufacturer, based on purely functional descriptions of the standard components of the automation system. The precise components with the specific performance characteristics of the respective supplier are not added until later.

The challenge

In modern production plants, components are increasingly being networked to each other and also to other parts of the value chain. Individual components are being equipped with a growing number of sensors and actuators, given their own intelligence and communicating independently with other components. This greater complexity also means that planning, commissioning and maintenance becomes more expensive and time-consuming.

Aim

The OPAK project aims to make this easier with "plug-and-produce". Plant planners and operators are to be given an assistance system which they can use to plan, develop, maintain and expand a plant using a 3D-supported user interface and hence in a less abstract manner.

Technologies

This focus here is on standardising interfaces, both of plant components and their mechatronic interfaces, as well as the connection between hardware and software. This approach enables real plug-and-produce so that individual components from different manufacturers can be combined to form an overall system without the need for special adaptation. The functions of the individual components are described in a standardised manner so that they reflect their physical abilities, and this benefits the designer who can, for instance, directly determine the route of mechatronic axes or conveyor belts instead of describing them in a manner that the computer understands. OPAK does this by automatically generating the corresponding program code for the machine in the background. Using 3D visualisation, the designer can directly track the effects of his changes and optimise the plant. Thanks to this progress, the plant engineer can focus entirely on programming the plant. The advantage of this is that in addition to making it easier to write control programs, the plant can already undergo virtual testing on the computer which means considerable savings.

Use Case

The results of the project will be demonstrated in four applications in research, industry and education. Taking the Asys Group and Festo AG as examples, the viability of the planned software architectures is to be tested in industrial production. Using specific mechatronic elements, such as grabbers, conveyor belts, pneumatic cylinders and electrical linear axes, simple production plant design will be demonstrated. This much simpler planning and commissioning of production plants will also be demonstrated in the Lemgo Model Factory at Ostwestfalen-Lippe University and in a modular production system at Festo Didactic and will pave the way for new possibilities in re-

search as well as training and advanced education because production plant design now no longer calls for special programming skills. 3D visualisation also means that staff can be quickly and easily trained in the different plants.

Partners
Festo AG & Co. KG (consortium leader), ASYS Automatisierungssysteme GmbH, elrest Automationssysteme GmbH, Festo Didactic GmbH & Co. KG, fortiss GmbH, Hochschule Ostwestfalen-Lippe (inIT), 3S-Smart Software Solutions GmbH

Contact
Johannes Hoos (hojo@de.festo.com)
FESTO AG & Co. KG

www.opak-projekt.de

Innovations with OPAK

Up to now	With OPAK
During the development and commissioning of production plants, the focus is on the individual components. The plant engineer must be able to understand, program and service these individually. As the number and complexity of components increases, so too does the expertise and work needed for integration and operation.	An intuitive planning and development tool means that the work needed to plan, test, commission and adapt complex production facilities can be reduced significantly.
Plant operators and installation contractors must master highly specialised information and network systems in order to program plant control systems.	Assistance systems conceal the technical details of information technology. This makes its easier to solve problems and to better implement optimisation solutions.
In order to control components, production plant engineers today have to deal with largely abstract control programs and input/output signals that differ from one manufacturer to the next.	Standards in component capability descriptions and a uniform communication protocol allow the focus to be placed on selecting the right components with a view to the functionality of the overall plant. Software tools make it easy to write specific control programs.
Due to manufacturer-specific interfaces, cable, hose and electronic connections for different components still require considerable time and effort.	Uniform definitions for hardware interfaces significantly reduce the time and effort needed for configuration and system integration.
The plans and drawings for a plant to be installed are very abstract and have very little in common with the appearance of the actual plant. This means that expertise is needed for changes or optimisation.	Using 3D visualisation software, plants can be planned and displayed as a very near-real plant. This means that changes and adaptations can also be carried out by the plant engineer or production technician without the need for specific expertise. All stakeholders in the entire value chain, from the device manufacturer to the operator, hence have the same intuitive view of the plant to be planned.
In heterogeneous plants, complete documentation of production operations is currently very time consuming.	Thanks to standardisation, production in its entirety can be recorded and documented in a uniform manner and in realtime. This makes optimisation and revamping much easier and requires fewer resources.

ReApp

Plug-and-play integration of robots into industrial automation

Brief description

ReApp defines standardised interfaces for integrating hardware and software from different manufacturers for robot systems. Together with a catalogue of reusable smart services (robot apps) and a model-driven development environment, robot systems are to be adapted faster and at less cost to the specific requirements of small and medium-sized enterprises (SMEs). In this way, SMEs are to be able to make flexible and economic use of robot systems production, assembly and logistics.

The challenge

Robot-supported automation systems are becoming increasingly complex. The time and money needed to program these systems, their integration, maintenance and adaptation are much higher than the actual cost of the components. This means that the use of robot-based automation systems in small numbers, as is often the case at SMEs, is often not economically feasible. Although software architectures that distinguish between programming individual components and programming the overall system already exist in research and consumer-based service robotics, these software architectures do not meet with the high quality and reliability standards required by industry. There is also a large number of components that cover almost the entire range of (robotic) functionalities, algorithms and control models. However, these are usually tailored to a specific application and hardware configuration. This is all set to change. The open-source ROS Industrial project is currently working on adapting the open Robot Operating System (ROS) software architecture to facilitate industrial demands while at the same time establishing standards for interfaces and the quality of ROS components.

Aim

The ReApp project takes up the concepts of the ROS Industrial project in order to define standardised interfaces and create software and hardware libraries that permit real plug-and-play for the most varied components. Together with a catalogue of reusable smart services and a model-driven development environment, robot systems are to be adapted faster and at less expense to specific requirements and especially those of small and medium-sized enterprises (SMEs).

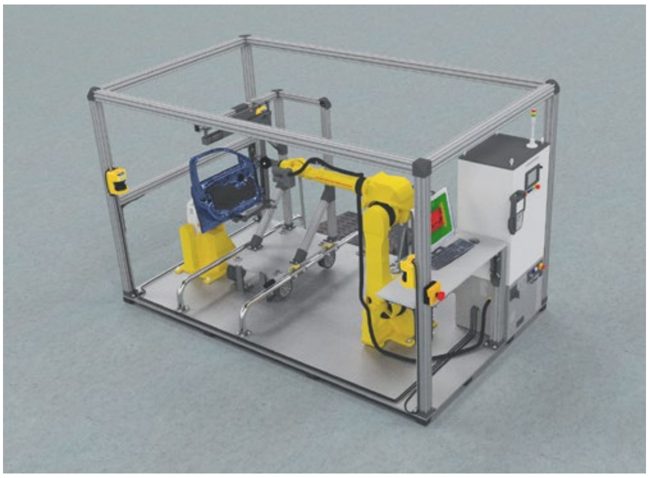
Technologies

An innovative, smart programming assistant is an integral part of the development environment. Without the need for special expertise, the assistant enables the user to set up his robot system for his application by identifying the hardware and software components in the library that are needed for the application and then automatically configuring the application once connected to the integration platform (another part of the development environment). Cloud-based simulation environments will also be provided for automated testing of components and applications and in order to meet high quality and reliability demands. The simulation tool ensures that virtual robot cells, for instance, or even entire production plants, can be tested and optimised before they are actually installed. ReApp will hence make it possible, especially for small and medium-sized enterprises, to boost their efficiency with flexible and reliable automation solutions. At the same time, the market for system integrators as well as robot and component manufacturers is growing.

Use Case

The ReApp concepts will be tested in three scenarios: two in the automotive sector and one in the electronics industry. In light of the growing number of vehicle models, automotive suppliers are finding it increasingly difficult to maintain the quality and delivery speed demanded with strong fluctuations in quantity. Workpieces for picking and assembly, as well as packaging of finished parts, are often carried out manually because these operations are (still) difficult to automate. ReApp will develop a demonstration system for this case where a robot can be easily and quickly fitted with different grabbing tools and sensors, depending on the product. The robot will primarily perform monotonous sub-tasks, such as counting, weighing and arranging different parts. Plug-and-play capability enables fast retooling for new orders and the programming assistant means simple adaptation of robot behaviour directly by the worker at the factory.

Flexibility and simple reconfiguration are becoming increasingly important for car manufacturers too. The technologies developed by ReApp will be demonstrated on the basis of door pre-assembly, gluing, optical quality inspection and bolting jobs which up to now could only be automated to a limited degree at a reasonable cost. Tailored solutions are also in demand in the niche market of circuit board assembly. The production of very small quantities is



currently carried out by SMEs for the most part for whom today's automation solutions are not commercially viable due to high hardware, software and integration costs.

Partners
Fraunhofer IPA (consortium leader), BMW AG, Dresden Elektronik Ingenieurtechnik GmbH, Fischer IMF GmbH & Co. KG, Fluid Operations AG, fortiss GmbH, FZI Forschungszentrum Informatik, InSystems Automation GmbH, ISG Industrielle Steuerungstechnik GmbH, Karlsruher Institut für Technologie (KIT) – Institut für Prozessrechentechnik, Automation und Robotik, Ruhrbotics GmbH, SICK AG

Contact
Dr. Ulrich Reiser (Ulrich.Reiser@ipa.fraunhofer.de)
Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA)

www.reapp-projekt.de

Innovations with ReApp

Up to now	With ReApp
Due to the lack of standards and interfaces, it is not possible to transfer controllers that have already been developed for a specific robot to a robot that is basically similar.	Thanks to ROS-Industrial interfaces, robot components and controllers can be replaced regardless of their manufacturers.
Today's software solutions designed for more than one manufacturer or component (e.g. ROS) are unable to meet with the high quality and reliability requirements in industrial application.	A uniform test platform enables automated application testing of real-time capability and reliability.
Due to the considerable work involved in programming and integration, robots are currently only efficient in automation when used in large numbers.	Standardised interfaces and intuitive programming environments make robots, even in small numbers, economically efficient, especially for small and medium-sized enterprises.
With today's automation solutions, customized adaptations require extensive time and effort.	The reusability of automation and software components enables a high level of product diversity thanks to flexible production plant design.
The current dominance of proprietary interfaces and software solutions is a barrier to the integration of components from different manufacturers to form a heterogeneous production plant and can only be overcome at considerable expense.	New integration platforms as well as interfaces standardised by the ROS-Industrial consortium enable fast integration of different components to form an overall system. Furthermore, other components can also be added if requirements for the production plants change.
As a rule, the user of robot-based automation solutions cannot access their programming. This means that any addition of new applications for an existing automation system will not be possible without the costly assistance of system integrators.	A smart programming wizard and an intuitive development environment for robot applications allow users themselves to make changes to the behaviour of their automation systems with relatively little time and money.

SMART FACE

Distributed production control for the automotive industry

Brief description

The aim of SMART FACE is to develop distributed production planning and control systems. This is designed to adapt manufacturing structures to the demands of small-series production; parts to be assembled are individually requested via a network-supported application and self-organised machines distribute their workloads, making central sequence planning unnecessary. The advantages of this approach are flexibility, easy adaptation and an improved response to unforeseen changes in the workflow.

The challenge

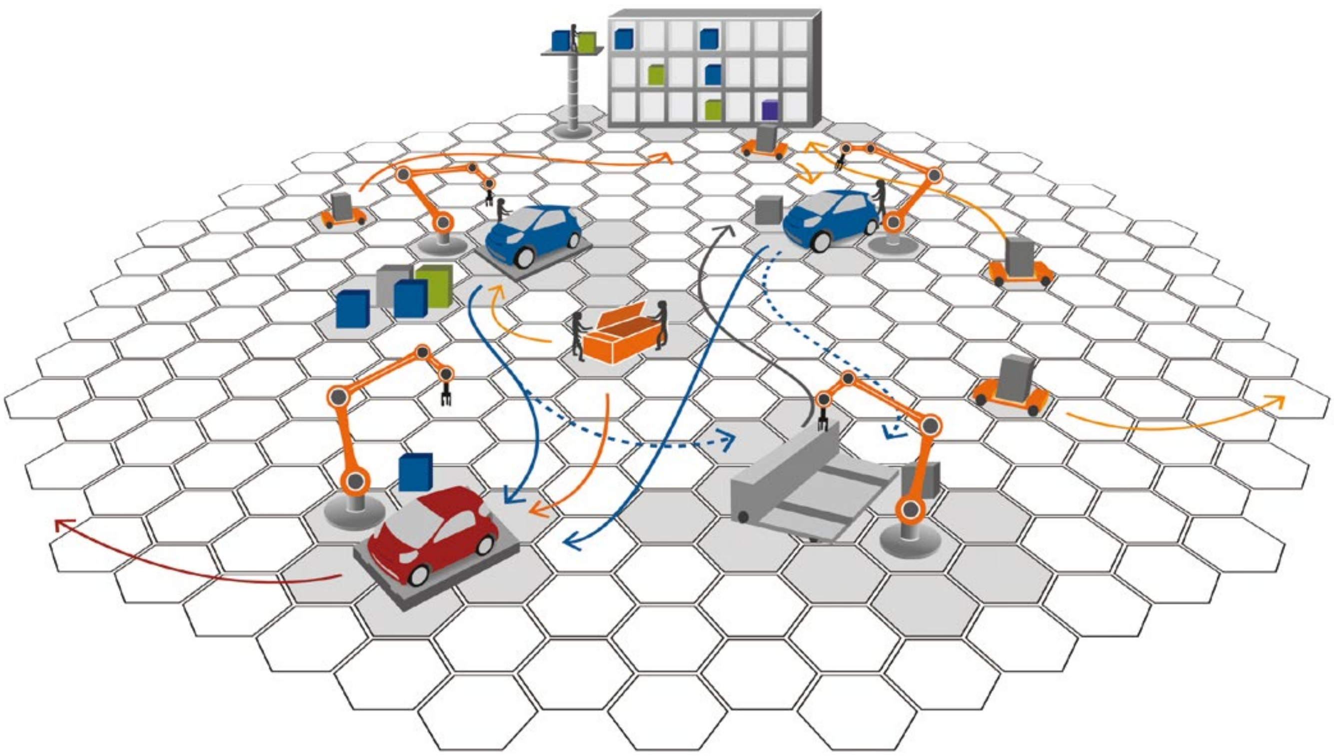
Today's production lines are characterised by high quantities and the highest possible efficiency. Productivity is the focus of large-series production. These rigid, inflexible and centrally controlled workflows guarantee economically efficient, but not individualised production. However, customised products are becoming increasingly important in many sectors. Configurators, for instance, for passenger cars or furniture, allow customers to shape design and execution to meet their specific needs. There is now a trend towards small-series production. But taking individual customer requests into account in the production of small product quantities is both expensive and time consuming due to long retooling times.

Aim

In order to make small series production both flexible and economically efficient, the SMART FACE project is developing new approaches for extremely flexible production planning and control. Single production steps will be supplied with parts and materials as required and always on time. This saves resources and avoids idle running.

Technologies

The core of this new approach is a production system with distributed control where materials and production parts make their own way from one machine to the next. This calls for continuous data exchange between the smart objects combined with flexible control. The key to this is smart, networked sensors that scan the environment and communicate both with each other and their surroundings. The continuous exchange of data can be used in this way, for instance, to directly organise supplier rela-



tions (when is the next delivery due?). So-called agents, equipped with appropriate software modules, check the exchange of information and decisions regarding logistics workflows. This form of distributed artificial intelligence ensures that production is self-organised to a large extent.

Use Case

The SMART FACE project will examine various fundamental challenges in pilot applications in automotive production. The key questions here are: How can information flows be parallelised with the material flow? How can responses to unforeseen changes in the production workflow be improved in terms of both time and quality? How is the intelligence of both objects and their sensors defined and which decision patterns must be defined? The solutions to all of the above challenges will be tested in the specific application case and are to be transferred to other sectors. Starting with the weaknesses in today's production methods, which basically do not permit any economically efficient small series production, new planning algorithms will be developed and integrated into an operating concept. Software components will also be designed which meet with the standards set by the automotive sector. The distributed material flow system will be simulated with a demonstrator and validated under real-life conditions.

Partners
Logata Digital Solutions GmbH (consortium leader), Continental Teves AG & Co. OHG, F/L/S Fuzzy Logik Systeme GmbH, Fraunhofer Institut für Materialfluss und Logistik (IML), Lanfer Automation GmbH & Co. KG, TU Dortmund, SICK AG, VOLKSWAGEN AG

Contact
Andreas Trautmann
(projektkoordination@smartfactoryplanning.de)
LinogistiX GmbH

www.smartfactoryplanning.de

Innovations with SMART FACE

Up to now	With SMART FACE
Small-series, customised production is both expensive and time-consuming.	The production of mini series with a high degree of individualisation is economically feasible.
Rigid assembly lines cannot respond flexibly to changes in demand.	Distributed, communicating smart sensors and material flow units enable extremely flexible production.
Production planning for highly efficient assembly lines is carried out via a central IT infrastructure.	Interaction between sensor systems, information and process management enables self-organisation of the material flow.
Today's algorithms support production planning and control for large series in flow production.	Improved load distribution, higher output quantities and optimised workflows are possible thanks to lean program planning.
When it comes to producing large series, fairly rigid central sequence planning is customary.	The distributed production system also optimises itself locally because the materials themselves adapt to the direct production demand.
Production planning is closely aligned to the individual case and is very rarely suitable for transferring.	A description model is created to basically structure production process data and to transfer this to a data model that can be adapted and transferred to other sectors.

SMARTSITE

Autonomous and networked construction machines and equipment in road construction

Brief description

SMARTSITE develops smart control systems for autonomous construction machines and equipment which are also capable of co-operating along the entire logistics chain. A model motorway construction site is being viewed as an application case where a control centre sends the work jobs to the construction machines and equipment and provides additional information, for instance, regarding environmental conditions. The development of uniform standards for exchanging data and providing information outside the scope of the construction site is an important aspect of this project. The overall goal is to significantly improve the efficiency of road construction and the quality of the roads build, especially with a view to longer durability.

The challenge

In road construction, bituminisation work is one of the critical steps. The slightest defects in the material properties or when laying or compacting the asphalt can impair quality significantly, a fact that is often not discovered until after the work has been completed. There are many reasons for this, including the many legally and economically independent stakeholders, a lack of communication standards, insufficient sensor technology, networking and use of existing data, as well as the lack of automation to date. The consequences are extensive rework, or in worst case scenarios, removal and reconstruction, and this can lead to much higher costs. In road construction, this can total up to 5 percent of the construction sum.

Aim

The aim of the SMARTSITE project is hence to develop open and flexible software platforms for smart construction site networks, construction process control, autonomous construction machines and equipment. These platforms will lead to automation of existing distributed systems and their networking with each other and the construction site environment on the basis of uniform standards. The improved exchange of information and the provision of information beyond the construction site fence promise vastly improved quality as well as economic and ecological benefits for projects.

Technologies

Bituminisation work calls for co-ordinated interaction between the laying of the material and subsequent compaction using a roller. SMARTSITE is developing algorithms for autonomous control of single, mobile construction machines and their co-ordination. Autonomous control responds here in realtime to current environmental conditions (rain, temperature, wind, etc.), material properties (e.g. asphalt temperature and density, compaction thickness) and machine conditions (e.g. position, loading status) in order to achieve optimum laying and compaction results. In the interest of quality-driven control, a vast variety of sensors are integrated into the construction material, into the construction machines themselves and even into the ambient environment and then combined with external information, such as weather service or traffic congestion reports to form so-called smart dust. This kind of construction site network requires a reliable and secure communications network where very different elements and processes can be integrated dynamically on the basis of uniform standards. The data continuously captured is used not only for smart control of the construction machines, but also for efficient monitoring and continuous documentation of the entire construction process for all stakeholders, from the machine operator and the construction supervisor to the customer. Intervention into all process steps is possible, no matter where no matter when, thanks to cloud-based services and mobile terminal devices. Using the construction site network, smart optimisation algorithms along the entire value chain in road construction, from the asphalt mixing machine and transport logistics right down to the individual construction machines, can boost the efficiency of energy and resource consumption.

Use Case

The innovations described will be tested in the field in different simulations, experiments and realistic application scenarios of a pilot project.

Partners

Drees & Sommer Infra Consult und Entwicklungsmanagement GmbH (consortium leader), Ammann Verdichtung GmbH, ceapoint aec technologies GmbH, Ed. Züblin AG, Universität Hohenheim, Topcon Deutschland GmbH

Contact

Dr. Burkhard Seizer (burkhard.seizer@dreso.com)
Drees & Sommer Infra Consult und Entwicklungsmanagement GmbH

www.smartsite-project.de

Innovations with SMARTSITE

Up to now	With SMARTSITE
Errors during manual or semi-autonomous construction site control in road construction lead to avoidable construction defects which have to remedied at considerable cost.	A significant reduction in defects thanks to optimisation and automatic monitoring of construction processes on the basis of autonomously controlled information exchange between construction machines, the construction site environment and construction supervisors.
Manually integrating new elements in the construction process into a static communication structure is extremely time consuming and expensive.	Uniform standards allow construction machines, ambient sensors and suppliers to be automatically and autonomously integrated into a dynamic communication network.
The position data of construction machines and materials can currently be detected only within the metre and centimetre range.	New localisation sensors allow much more precise detection in the millimetre range for precise, autonomous construction machine control.
Only the construction machines can send information regarding construction activities to the control centre. Error intervention is only possible at a different time and place.	New communication infrastructures enable exchange between systems, construction machines, the control centre and mobile terminal devices. Any deviations from planned processes can hence be detected and remedied faster, more comprehensively and on site.
The impact of environmental factors, such as temperature, rain, wind, as well as delays in delivery, on the construction process is difficult to assess with precision and this can only be carried out on the basis of the personal experience of staff.	Environmental impacts are automatically detected by sensors and via a smart controller they directly influence the construction process, thus boosting the quality of the work to be performed.
Data that is relevant for control can only be recorded for a specific site.	Cloud-based architectures enable site-independent access to all data relevant for the construction process. This means that intervention in machine control is possible at all times and from different points and automatic quality and defect reports can be created. Data protection is ensured at all times by smart authentication mechanisms.
Today, data from individual machines can only be displayed via simple tablet applications.	Mobile, app-based solutions enable visualisation in the cockpit of the machines for individual control as well as for overall quality management.
It is extremely difficult to optimise energy and resources because data is either distributed or not gathered.	Smart linking of all data that is relevant for the construction process enables considerable optimisation of environmental compatibility as well as energy and resource consumption.

SPEEDFACTORY

Automatic custom manufacture of sports shoes and textiles

Brief description

Automated custom production is being developed in the SPEEDFACTORY research project where humans and machines are working together in a common working environment to produce sports goods and car seat covers in the shortest possible time, from the design to the final product at a low-cost and in a flexible manner.

The challenge

Textile products have been produced for decades in two different scenarios: They are manufactured either at low cost in huge quantities in industrial mass production or at considerable expense in small numbers in less automated settings. The value chains in the fashion and sports industry are globally networked. Product management, design and production often take place on different continents. Optimisation cycles or changes in appearance and textile properties or composition are both time-consuming and call for a high degree of flexibility from the stakeholders involved. The logistic challenges of a value chain that requires a permanent exchange of information, design suggestions, patterns and finished products between Asia and Europe make high-quality production both difficult and expensive. Short model cycles or low-cost small-series production are almost impossible, but are becoming increasingly necessary due to customer demands. With current production processes, this trend towards low-price customising is neither economically nor technically possible.

Aim

The SPEEDFACTORY project aims to combine the various advantages of the different production approaches in one new method. The aim is industrial micro-mass production down to batch size 1. Using the latest technologies and enhanced man-machine interaction, short cycle times are to be achieved combined with outstanding flexibility. The goal is to avoid transactions across different continents. The production of fashion and sports goods is to be increasingly brought back to Europe. Competitive strength is to be stepped up through shorter logistics channels (physical and informative) and hence by a faster response to customer requests and fashion trends.

Technologies

The project partners expect to achieve prototype production of sports textiles and shoes and of seat covers for vehicles using innovative production processes without any losses in value added. This calls for smart factory concepts with a high degree of automation and cognitive skills among the workers interacting with the machines. Certain production steps will first be modularised in order to make processes more efficient. The co-ordination and control of the individual modules are largely automated and distributed. The use of individual materials, which up to now could not be processed by automated machines, will be extremely important for workers and their interaction with the production robots. Economically sound interaction between man and machine only becomes possible when innovative sensor technology, ambient intelligence and cognition are used in conjunction with augmented reality.

Use Case

As part of this project, a factory demonstrator will supply prototypes to show the new production options.

Partners
adidas AG (consortium leader), fortiss GmbH, Johnson Controls GmbH, PFAFF Industriesysteme und Maschinen GmbH, RWTH Aachen

Contact
Jan Hill (Jan.Hill@adidas.com)
adidas Group

Innovations with SPEEDFACTORY

Up to now	With SPEEDFACTORY
Textiles and shoes are largely produced in Asia.	Thanks to state-of-the-art technologies, production is to be more site-independent and mini-series, for instance, are to be produced in Europe.
Textile manufacturing is carried out either fully automated or manually by specially skilled workers.	As a result, automated process steps and human skills will be excellently co-ordinated.
From design to production, global communication and production steps are only possible in long cycle times.	The aim is product manufacturing as single-piece or small series production in short cycle times, in a matter of days.
Long cycle times in production due to high logistics and information costs	Product designers and developers can implement their ideas ready for series production in the shortest time.
Planning and control systems are centrally designed, built for mass production and are very difficult to adapt to small batch sizes.	Modular manufacturing steps make production extremely adaptable.
The rigid layout of series production lines hinders flexibility.	Thanks to modular software and hardware components, factories can be designed to facilitate change.
Workers perform individual work steps within mass production.	Humans are supported by robot systems so that they can make the best use of their manual skills.
Draft designs have to be translated into production specifications in a time-consuming process.	SPEEDFACTORY enables the production-compliant transfer of 3D design models from software to the machine controller.

AUTONOMICS, Industry 4.0 and law

The “AUTONOMIK für Industrie 4.0” concept includes a host of technical, organisational and economic innovations which have been almost impossible to assess up to now in terms to their reach and impact. Although revolutions like these affect legislation, resulting in more or less quick change, the legal framework is extremely important for the development and implementation of innovations. This is particularly true in a country like Germany with its highly developed legal system based on the rule of law and a very active legal policy. Laws can hinder innovation, but they can also promote it.

The legal challenges facing Industry 4.0 are closely linked to legal issues regarding autonomous systems and, in some cases, go far beyond this. The most important difference, from a legal perspective, between the predecessor project “Autonomics - autonomous and simulation-based systems for medium-sized businesses” and “AUTONOMIK für Industrie 4.0” is the comprehensive networking that is part of the design for Industry 4.0. The resultant legal questions have been mostly discussed up to in the field of Internet law which has attained new and in some areas crucial importance.

Many of the legal issues brought up are closely linked to the new quality of machine networking. That’s why the first step in examining the relevant legal issues understandably begins with Internet law (including provider liability law and complex cross-cutting issues involving elements of civil, criminal and public law). As in the predecessor programme, the AUTONOMIK für Industrie 4.0 topic throws up significant questions regarding liability for damage to machines, products, other assets and injury. From a civil law perspective, tort law and product liability law are important, however, criminal law is also relevant. It should be remembered that injured parties will often recourse to criminal law simply for reasons of securing evidence. In order to avoid liability (also in growing M2M communications), it is imperative that the machines and devices used within the scope of Industry 4.0 be equipped with a host of sensors that can capture and process large quantities of ambient data and trigger suitable safety responses. The vastness of the data captured, however, leads to considerable problems with data protection law.

With a view to liability (under civil and criminal law), the right balance between technical rules and the legal criterion for negligence must be found. Considering the high level of many technical rules, it is regrettable that up to now both worlds, i.e. technical regulation and legal regulation, have existed largely independent of each other. It is now time to transform competition into synergy. Certain sensitive data is also protected by copyright and this must also be examined. In the event of injury, applicable supplementary penal provisions will also become relevant.

Man-machine co-operation is extremely important within the context of Industry 4.0. This poses a huge challenge for labour law and especially for occupational health and safety law. All employees working within the scope of Industry 4.0 can come into contact with smart machines. Special attention should be paid here to the considerable public relevance of the issues mentioned which can determine whether or not innovative, technically organised concepts are accepted by society. This is the reason why the relevant issues must be identified as early as possible and proposals for solutions developed. Following the first phase of analysis, these proposals can then be introduced into the social and political debate.

IT security for Industry 4.0

For a long time, production plant security was interpreted as operating safety , i.e. uninterrupted operation of the plant without any risk of injury. With the use of computer-based and, at times, networked machines in production, a new security requirement arose, i.e. information security. With the cyber-physical systems in Industry 4.0, the degree of networking and the "intelligence" of the components continue to rise: Workpieces, machines and conveyor systems are now components of an IT network which permanently communicate with each other and with external parties. The workpiece makes its own way to the machine which reports to it that it has free processing capacity; through self-diagnosis, the milling machine detects that its cutting tool is worn and informs the production technician who finds out about the status of the machine through remote access and can then plan tool replacement. Just like any other ICT network, this production network can also be attacked, spied on and disrupted. Under certain circumstances, this could pose a risk for life and limb and result in high costs due to production downtimes or the loss of confidential information.

Technologies, methods and standards for protecting information security are well-known from the world of information and communication technology. Despite this, there are still considerable challenges facing communications with new cyber-physical systems in production.

- When it comes to classical operating safety, there are already established methods for assessing risks as well as quantitative testing and certification methods. In contrast to this, it is assumed in information security that an attacker will proceed in a targeted manner and adapt his approach to overcome the existing protection measures. Attacks will also become easier as technology progresses: In the future, powerful computers will be able to break key lengths that are today considered to be secure. That's why there is no permanent degree of information security that can be technically achieved once and for all and then certified. Instead, it is possible to demand the existence of certain security management systems and the use of technologies that are considered to be sufficiently secure. Despite this, a breach of information security can also threaten operating safety, for instance, if emergency equipment is switched off. Both security and safety are becoming increasingly interlocked even though there are still no practical approaches that allow both aspects to be jointly considered in technical guidelines and accreditation.

- The timely availability of information, for instance, for machine control, often plays a much more important role in production than in other IT networks where short delays can be accepted. The security technologies must take into account this specific priority of the protection goals in production and must be adapted if necessary. Installing updates of security software (patches) at short notice, for instance, is not possible if this disrupts production workflows.

- Under some circumstances, the production network can include a large number of partners, suppliers, customers, logistics firms and other service providers. This means that customary procedures for setting up and operating security management systems, which up to now were primarily geared to implementation in a given organisation, must be expanded accordingly. Even the maintenance technician from an external company who accesses a CNC machine remotely or on site using a laptop, or the IT infrastructure of a small supplier company must be adapted to meet the needs of security management.

In the producing sector, there are many questions that have yet to answered regarding the security of networked and ever-smarter machines and systems in this sector. One of the key topics of scientific assistance for "AUTONOMIK für Industrie 4.0" is hence information security when autonomous cyber-physical systems are used in production. The central issues here are:

- Which of the known security methods and technologies make sense and are suitable for this kind of application, and how, when necessary, can they be adapted and upgraded?
- How can the relationship between information security and operating safety be properly defined and warranted?

The future of work in Industry 4.0

In much the same way as industry is being fundamentally transformed, work too will undergo far-reaching change. New qualifications, new thinking, new forms of organisation and communication will revolutionise the working world. It is still not possible to envisage how jobs will look in the future. But the time has come to make it possible to estimate and describe the new requirements. That's why from the very beginning the Industry 4.0 concept focused so strongly on labour design and the future of work. A comprehensive approach will be needed in order to turn the Industry 4.0 project of the future into a strategic lighthouse and a guide for innovation policy in Germany. What is clear is that an innovative society needs innovative industry, and innovative industry needs innovative workplaces.

The innovative capacity of companies depends not just on R&D budgets, co-operation with external research institutes and highly qualified staff in the company's own research departments. Innovative capacity calls for a high degree of communication and co-operation across all areas of the company: from R&D to design and work planning, right through to production, sales and service. In order for this kind of co-operation to work and to ultimately lead to first innovations, it must be ensured that the conditions necessary are created at all of the workplaces. This includes, for instance, possibilities for participation and room to decide and act, demanding tasks, possibilities to learn on the job, transparency regarding workflows, even beyond the worker's own workplace and department, as well as a strong culture of information and feedback. These conditions are primarily determined by the company's organisational philosophy and then by the technical systems that are embedded in this organisational philosophy. Both of these, i.e. organisation and technology, must be considered together with people and their needs when designing work in Industry 4.0.

These issues are addressed in a cross-cutting topic in scientific assistance for "AUTONOMIK für Industrie 4.0". The central tasks of this cross-cutting topic are:

- To process the status of technology and science through specialist publications and guides designed to accommodate practical application
- To process examples of good practice from the AUTONOMIK für Industrie 4.0 projects and beyond
- To initiate and provide ongoing support and moderate dialogue between the AUTONOMIK für Industrie 4.0 projects on the topic of „The Future of Work"
- To include in this dialogue specialist communities and other stakeholders, such as social partners
- To publish work-related results together with the projects

The aim is to help pave the way into a new working world which will be decisive for future generations.

Standardisation

Standards create a sound basis for technical procurement, they ensure the interoperability of the application, they protect the environment, systems and consumers through uniform safety standards, they are a future-enabled basis for product development and support communication among all stakeholders thanks to uniform terms and concepts.

Standardisation has a key role to play in the success of Industry 4.0 as a project for the future. Industry 4.0 calls for unprecedented integration of systems across domain borders, hierarchy borders and lifecycle phases. This is only possible with consensus-based specifications and standards. Close collaboration between research, industry and standardisation is necessary in order to create the preconditions needed for far-reaching innovation, i.e. methodological foundation and functionality, stability and investment security, practical suitability and market relevance.

Timely stabilisation of concepts through a consensus-based standardisation process during the research phase is essential if fast implementation in industrial applications is to be possible. This explains why the topic of standardisation in conjunction with Industry 4.0 and the Internet of Things and Services is the subject matter of a number of different activities:

- Industry 4.0 standardisation roadmap (DKE/DIN)
- Industry 4.0 platform, working group 2
- DIN/DKE working group “Industry 4.0 standardisation”
  Current topics
  - Radio technologies
  - Continuation of the Industry 4.0 standardisation roadmap
  - Presentation of the standardisation landscape
- IEC/ISO: Automation systems, ICT, functional and IT security, robotics, semantics, hardware integration, etc. (see standardisation roadmap)
- VDI/VDE-Gesellschaft measuring and automation systems (GMA)
  Publications on the topic
  - Value chains
  - Objects, entities, components
  - Reference model
- Global developments of specifications in forums and consortia in the world of ICT (e.g. M2M, IoT, wireless)

Many standards already exist. As developments in Industry 4.0 and AUTONOMIK für Industrie 4.0 progress, existing standards should be adapted, where necessary, or developed further, or new standards must be drawn up. Especially when it comes to cross-cutting and domain-spanning topics, it becomes apparent that the standards of individual domains come into contact with each other and cannot be migrated until a systematic approach in standardisation is adopted. The following steps are examples of what is needed:

- Creation of a joint foundation based on a uniform system approach (e.g. through use cases, reference models)
- Information about and overview presentation of the heterogeneous standardisation landscape (status quo)
- Definition of an additional need for standardisation (modification, new standards, uniformity) and implementation of a corresponding work programme
- Compilation and development of Industry 4.0 profiles
- Implementation and testing

That’s why the “AUTONOMIK für Industrie 4.0” technology programme has an interest in a bidirectional exchange of information with the world of standardisation:

- Receiving information about the current status and latest developments
- Including developments from research projects in standardisation as quickly as possible

In this way, new ideas can directly influence the current development of standardisation. Another advantage is that the projects can supply input and support the development of standardisation. Successful standardisation provides an important tool when it comes to translating innovation from the research stage to marketable products and services. That’s why from an early point in time scientific assistance, in co-operation with the projects, aims to monitor the developments taking place in the field of standardisation, to initiate its own standardisation projects and to both accompany and provide helpful support for current developments.