Digitalized Production

# Industrie 4.0

## Flexible Transparent Manufacturing

**Manufacturing small and fluctuating batch sizes while still keeping costs stable is an increasing demand in industry. Yet if production becomes more flexible, processes become more complex, increasing the danger of unmanageable procedures making production inefficient. Fraunhofer IPK demonstrates with a specially developed scenario how digitally integrated technologies facilitate transparency in flexibly organized production. The possibilities offered by novel technologies will redefine the tasks and work of production employees along a process chain from corporate-wide job management through manufacturing organization to work on individual machines.**

### ► Gear Production Scenario

Industrie 4.0 promises mostly one thing: Great flexibility in production. In the future it will be possible to adapt production to ever-changing versions of products and processes and still keep costs stable. Ideally, developments will even allow small and smallest batch sizes to be realized without causing production costs to explode.

To show how production may be structured more flexibly, Fraunhofer IPK has developed a complex scenario using the example of gear production. Gears are presently manufactured in firmly linked lines that are laid out to produce specific components and which, for example, employ interconnected milling and turning machines. The entire line comes to a standstill, if a single machine goes offline. In addition, it is complicated, if not impossible, to adapt lines to changing product ranges or to produce orders to special demands.

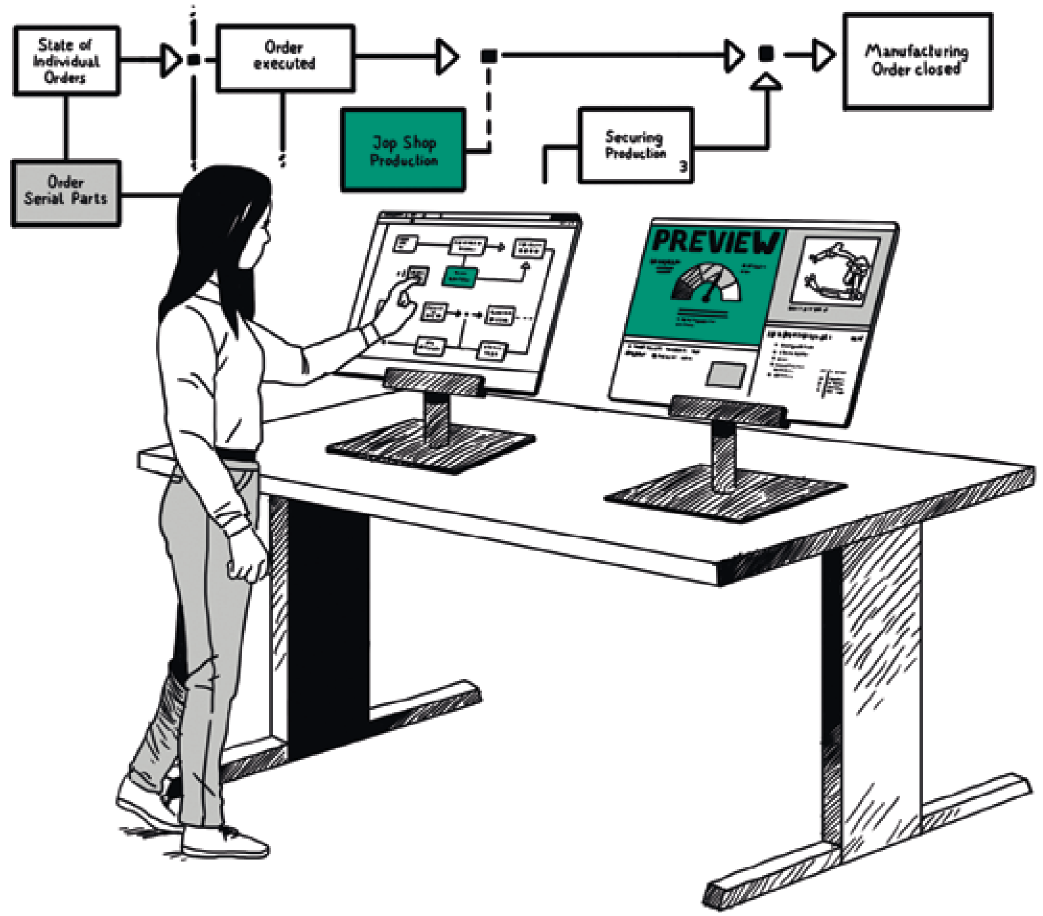
Greater flexibility in this regard requires that such interlinked structures be broken up. One way to do so is to employ the job shop production principle. It groups machines that may be employed in similar manufacturing tasks – for instance, several turning machines could be combined into a turning machine group – which permits orders to be guided flexibly through the manufacturing process. It also allows machine groups for different machining tasks to be laid out in different sizes – greater capacities, for instance, could be facilitated for machining processes that are more time-consuming. The result would be a significant improvement in response times and capacity utilization.

Such a factory layout makes it possible to adapt processes in response to job-specific requirements at any time. On the one hand, it allows, for instance, an order to be turned on all the turning machines available in a company. On the other hand, process steps can be combined in new sequences again and again, additional steps can be added or unnecessary ones taken out. However, dynamic process networks place high demands on coordination – it must be ensured that all participants are able to keep track of everything at all times, if processes are to remain manageable. Also, alternative methods must be applied to meet one major demand that linked manufacturing fulfils: Reliable production flows must be guaranteed as otherwise processing steps could be overlooked or orders might stall halfway through production as a result of being repeatedly delayed in favor of more urgent jobs.

### ► Digital Technologies for Flexible Process Networks

This is where the new opportunities of digital networking are brought to bear, because they support the definition and practical application of flexible process networks which can be adapted to changing requirements. Such systems put people at the center, because it is the staff at all levels of production plants who are responsible for making sure that workpieces move through the production process on time. So, in order to ensure that the tasks are carried out reliably in a process network that consists of many minds and manufacturing stations and whose composition could vary slightly with each version of the product, intelligent technologies deliver the necessary transparency and continuously monitor the actual progress of work by comparing it against the scheduled and demanded deadlines. Such concepts also make Industrie 4.0 interesting to small and medium-sized businesses, because they allow the creation of considerably more adaptable flow controls while keeping investments and the implementation effort manageable.

The IPK scenario illustrates what a paradigm shift in the organization of production could look like along the process chain – from corporate-wide job management to work on individual machines. The five parts of the scenario present technologies developed and results achieved in the MetamoFAB, iWePro and pICASSO projects and in IPK's preliminary research. They show how the tasks carried out by workers in different parts of a production company could be redefined through the use of networked technologies. Greater flexibility will be made controllable by greater transparency. Companies will therefore become fit for customer-specific manufacturing.




**»I know exactly which stage each job is at – and provide every employee with precisely the information they need for their tasks.«** Chief Operations Officer

### ► Part 1: Industry Cockpit

The most important demand that needs to be met to prevent flexible networks from ending in chaos is that everyone must be able to keep track of what is happening at all times. If processes are to become adaptable without making production uneconomical as a consequence of the resulting administrative effort, companies need a dynamic control center that keeps every member of staff directly and in a task-related manner up to date on what they need to do to help carry out an order and when to do it.

Fraunhofer IPK's Industry Cockpit, developed in cooperation with Pickert & Partner, an MES manufacturer based in Karlsruhe, meets these demands. The Industry Cockpit has been developed to reliably monitor and control flexible process networks. It uses models to bring together all the information and processes available within a company so that it becomes possible for them to be accurately monitored and easily tracked. Such monitoring and tracking facilitates a precise overview of the plant's overall situation – of both processes and the condition of the manufacturing equipment.

Industry Cockpit enables individual views and dashboards to be automatically generated from the available data. Shop floor employees, shift supervisors, sales representatives, and managers can directly access this information from their workplaces. Working with the data turns each member of staff into a »process controller« for his or her specific areas of responsibility. And as staff complete their tasks, the cockpit automatically adapts the information for all other parts of the process that may be affected by their activities. As a consequence, on the one hand cooperation between different disciplines is encouraged – all members of staff remain within their disciplines and do what they do best while, at the same time, they can always see what effects their decisions are having. This is a solid base for process responsibility to be lived. On the other hand, executive levels always have an exact overview of the company's overall status and its individual orders at their disposal.

### ► Part 2: Production Planning

The iWePro project is striving to do the same for production flows as the Industry Cockpit is doing for process networks. In other words, the project aims to ensure reliable throughputs while information transparency and a partial decentralization of process responsibility support flexibility. Once customer orders reach production, they need to be assigned and scheduled according to the shop floor's capacities. Production management plans production flows using machine allocation schedules so that orders can be carried out cost-effectively and in accordance with requirements. These schedules specify which production step of an order has to be carried out on which machine and when.

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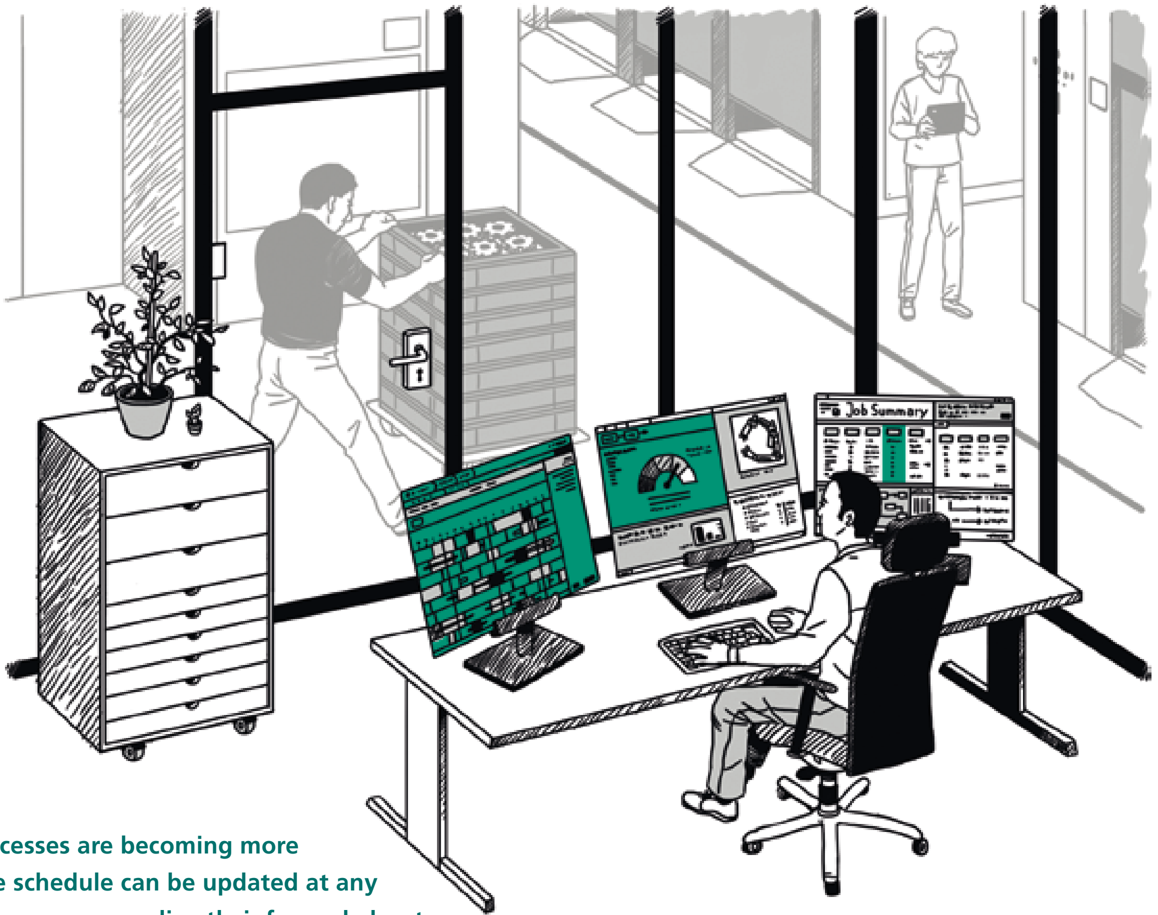



**»Manufacturing processes are becoming more flexible, because the schedule can be updated at any time and the workshop crew are directly informed about their tasks.«** Production Manager

Such scheduling so far is largely rigid and the leeway for later rescheduling is limited. If adjustments become necessary during production, for instance if a machine fails or a more urgent job demands prioritization, usually production management has to take action: It is required to act as a »fire fighter« and reschedule or approve changes. In addition, traditional scheduling makes sharing the plans with production staff time-consuming and inflexible: It requires the information to be communicated in briefings that are usually held at the beginning of shifts. Any later changes that result from revised planning make further meetings necessary. Such procedures are too rigid to allow production processes to be flexibly structured on the basis of the job shop production principle. That is why iWePro combines a modern tool for scheduling with an agent-based assistance system. This produces a system that allows production management to initially plan machine allocation centrally, but then enables dynamic adjustments to be made with its help. So, if changes become necessary during production, it is possible to modify the plan with little effort and the assistance of the agent system. Such adjustments may be initiated both by production management itself and by employees on the shop floor. And because both are working on the same database, it is guaranteed that production management always has a complete overview of the current planning and work status to hand.

Another benefit the system delivers is that it allows the plan to be communicated more directly with employees. Networked technologies allow each member of staff to access those components of the plan that are relevant to them directly at their workplaces on the shop floor. This reduces the time spent on briefings and makes it possible to easily and directly communicate changes in the plan to the production staff.

### ► Part 3: Shop Floor

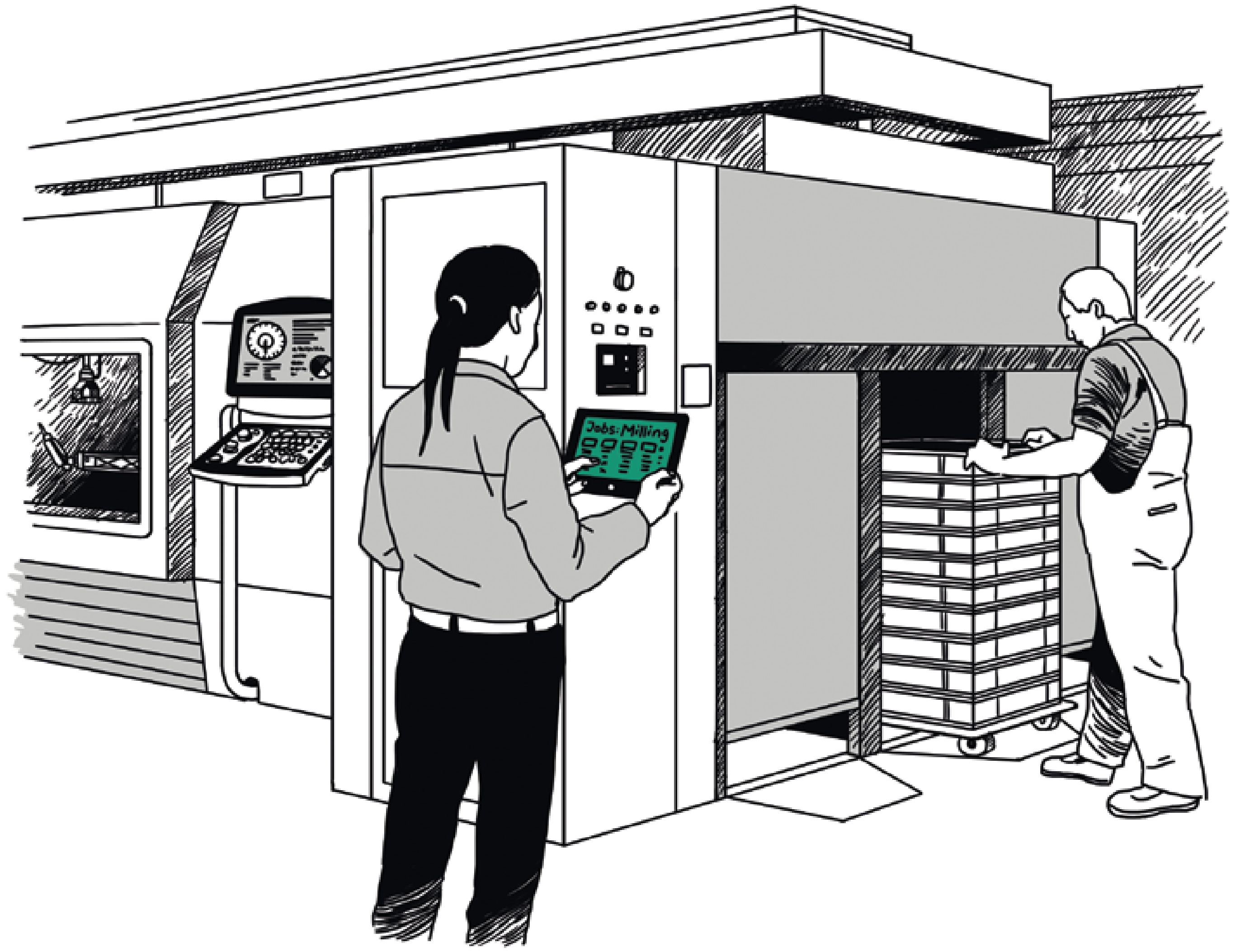
A dynamically changeable scheduling control as it is being developed by iWePro produces enormous changes on the shop floor as it shifts responsibility for processes and therefore necessitates adjustments to the activity profiles of certain groups of employees. Shop floor employees are currently usually required to execute a production plan drawn up by production management without deviations. But, in future, they are going to have a decisive say in workflows. Such involvement will require either additional qualifications or intuitive tools that provide support in carrying out the extended tasks.

The concept employed by iWePro assumes that in a production set-up applying decentralized job shop production teams of employees share responsibility both for a group of machines – for instance, for a certain number of turning or milling machines – and for the process steps associated with these machines. Corresponding excerpts from the machine allocation schedule are individually adapted to their requirements and provided to them directly at their workplaces so that they can at all times be kept up to date about which processing steps for an order have been assigned to which of their machines. But they will not only be able to read the plan, they will also be able to actively intervene. If delays, machine downtimes or other events prevent the plan from being followed, they themselves can change how the machines in their work area are scheduled.

In order to ensure that such reconfiguration creates as little disruption as possible, employees will be supported by an agent-based assistance system. This system takes account of such factors as the specific order's anticipated completion date, the availability of staff, machine conditions, and upcoming maintenance requirements and costs. Building upon this basis, it will make adjustment suggestions that the production staff can take into account when amending their plans. The system will also take care that any later processing stages or parallel jobs affected by the rescheduling will also be adapted and that all members of staff affected as well as the management level will be informed about the changes.

Intelligent machine tools deliver a further benefit in the decentralization of process responsibilities. They constitute an important link between scheduling tasks and physical processes. Equipped with sensors, they are able to analyze their own states, anticipate maintenance requirements and report capacities. In addition, virtual machine tools allow all machining operations and tool changes within the flow to be simulated before a new production sequence is commenced. This will support production staff in assuming production-manager responsibilities.

**»I take on responsibility for the part of the manufacturing process that runs on my machines and I can change the schedule as needed.«** Machine Operator



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**► Part 4: Shop Floor Logistics**

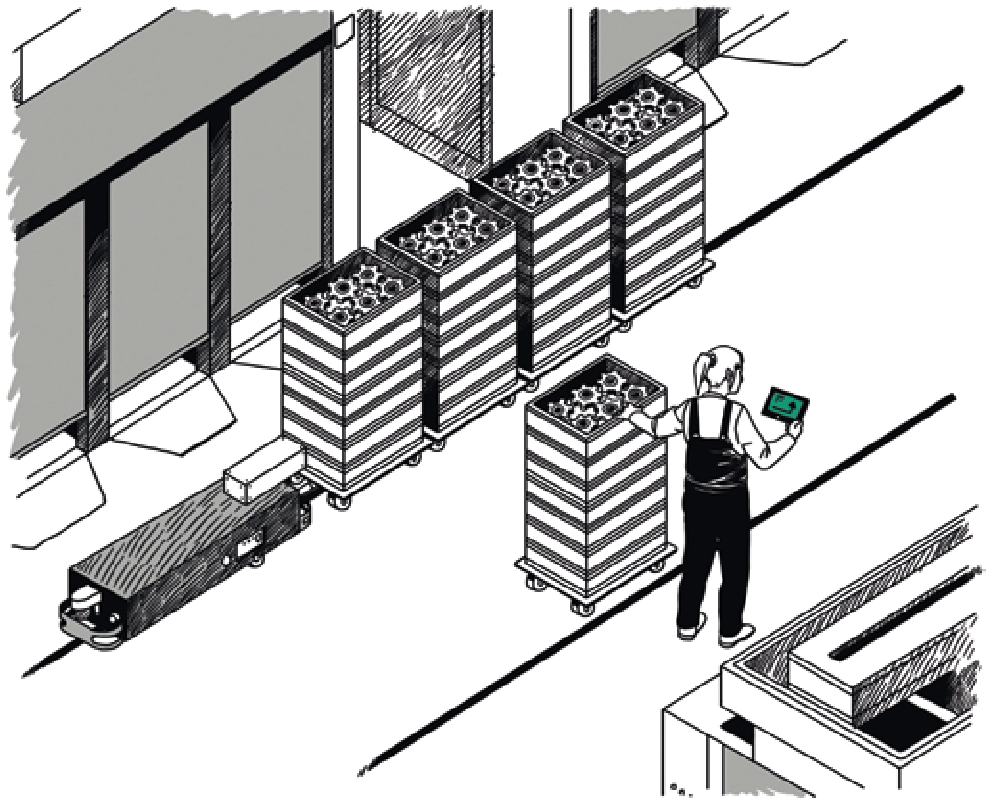
The smooth running of job shop production does not only depend on intelligent tools controlling the individual production steps. How the routes between the steps are organized is just as important.

It is relatively easy to reorganize transports between machining stations within a production area, which so far are ensured by the links. These transports can be carried out manually by the machine operators on the shop floor. Separate transport-management systems are not necessary here, because the transport requirements may be drawn from the scheduled production flow: Once the staff have been informed that after machining on machine A an order needs to get to machine B for further processing, they will be able to arrange the required transport between the two machining steps by themselves.

iWePro additionally factors in the longer transport routes between production areas – in other words from soft machining to hardening, from there to hard machining and finally to the end-of-line buffer. An intelligent transport-management system, developed by SAFELOG GmbH, could be used for the adaptive organization of transport. The system does not only emphatically organize the transportation required between the production areas to ensure that nothing can be forgotten, it also provides for optimum logistics planning that utilizes the available resources – staff and vehicles – in the best way possible. The final decision about the implementation details, however, is left to the staff with responsibility for production logistics.

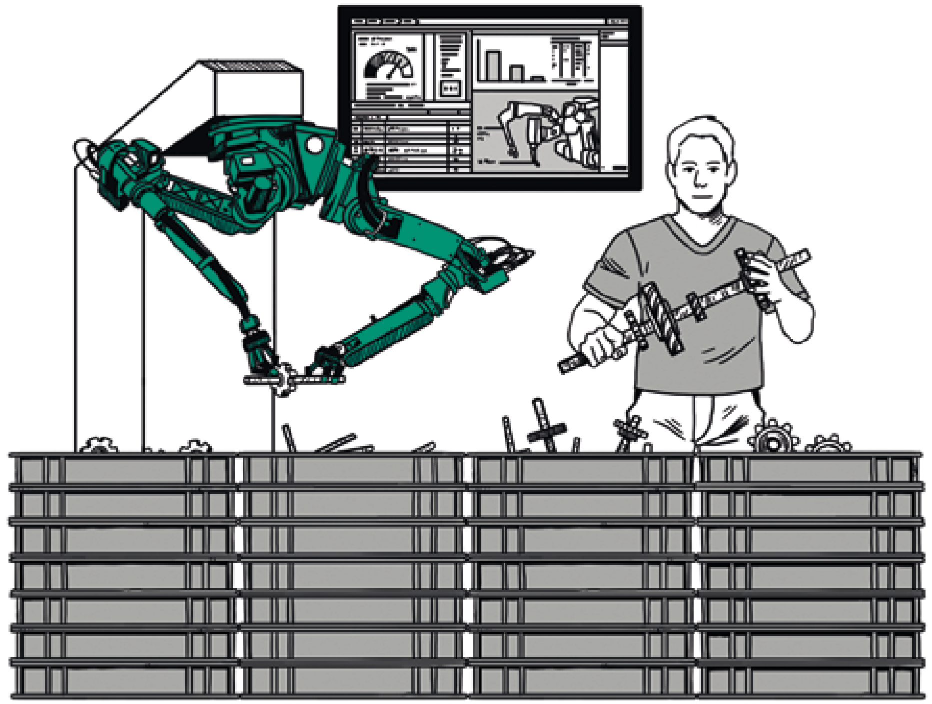
The system informs logistics staff on mobile devices about the type, scope and deadlines for upcoming transport jobs while also handling basic organizational tasks for each transport job. The most suitable means of transport is initially chosen from those available depending on the route, distance and scope of the transport job. These may include manual carts and trolleys, but also automated guided transport systems or trailer units that can be coupled and towed by powered vehicles. For jobs where a non-automated means of transport – i.e. transport by a member of the logistics staff – is selected, the system provides the appropriate member of staff with instructions similar to those familiar from navigation systems.

**»I always know exactly which job is headed where and when – and how to best ensure it reaches its destination.«** Logistics Team Member



**► Part 5: Assembly**

Last but not least, the production of components with customer-specific characteristics requires innovative robot systems that are able to rapidly adapt to new product variants or tasks. Such robots possess multi-arm systems with articulated hands, tactile and visual sensors, as well as new types of controls that include impedance, force and visual control. These technologies are enabling robots to carry out complex assembly tasks despite of errors and tolerances – they can now, for instance, assemble gears on shafts. This does not only make them more flexible, it may also change their field of application: New types of robots are able to assist people working in complex assembly processes and to minimize physical or mental stresses – e. g. when handling heavy parts or with monotonous repetitive tasks – or even relieve employees completely of these burdens. They will also increase the opportunities to optimize capacity utilization in factory assembly departments, because it will become possible to distribute jobs flexibly between staff and robots depending on the job and attendance situation.



**»For us, humans and robots are colleagues: They share the same work space and complement each other's skills, working together to complete assembly tasks.«** Head of Assembly

The new robots are able to actively communicate with people using spoken language, gestures and similar forms of interaction. They also detect the presence and movements of people in their work area and adapt their behavior accordingly. In addition, they provide advance notification to people about their own activities and movements. The most important features that the new robot systems offer are their innovative programming and controls, which make it possible for people to intuitively and interactively instruct robots using voice and gestures or to efficiently program them graphically with the help of prepared modules. Robots will be programmed and controlled on a behavior-oriented basis to enable them to rapidly adapt to dynamically changing environments, whereby different robot skills will be activated depending on the environment and tasks. Increased safety using advanced visual, tactile and other sensors enables the new robots to share the workspace actively and dynamically with people.

Finally, by incorporating robots and machines into such systems as the Industry Cockpit, they can be remotely monitored, and quality-relevant information can be observed and analyzed during the process. Such tracking makes it possible to detect sources of errors at an early stage and minimize delays caused by machining errors or machine failures. Also, machine operators will be significantly supported in their task of ensuring the availability of »their« machines. The resources required to this end could, for example, be made available through the cloud. ■

**Fraunhofer IPK at Hannover Messe 2016**

Fraunhofer IPK demonstrated its scenario for flexible transparent manufacturing at Hannover Messe 2016. The exhibit featured five stations presenting technologies developed and results achieved in the MetamoFAB, iWePro and pICASSO projects and in IPK's preliminary research. The presentation at the fair was realized in close cooperation with the partners involved in the projects: MetamoFAB – Pickert & Partner GmbH; iWePro – Adam Opel AG, DMG Electronics GmbH, flexis AG, SAFELOG GmbH, SimPlan AG, Sociological Research Institute (SOFI) at University of Goettingen, TAGnology RFId GmbH; pICASSO – Comau S.p.A..

The research and development projects MetamoFAB and iWePro are funded by the German Federal Ministry of Education and Research (BMBF) within the program »Innovations for Tomorrow's Production, Services, and Work« and managed by the Project Management Agency Karlsruhe (PTKA). The author is responsible for the contents of this publication.

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