# ENHANCEMENT OF PERSONNEL COMPETENCE IN INDUSTRY 4.0 PRODUCTION ENVIRONMENT BY USING SMART DEVICES

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***Abstract:*** *At Fraunhofer IPT we are realizing industry 4.0 through the adaptive digitalization and networking of machines, parts, personnel and other entities in the working environment, in order that information and instruction will be available everywhere and all the time in the production process. With analysis of big production data including machine states and product information gathered in the manufacturing, a predictive production process will be possible, which leads to the reduction of raw materials and scrap parts and to shorten the makespan. In addition, smart devices will play a very important role to help people being integrated in the future manufacturing environment. In this paper, we present our current development progress within the from the German Research Foundation DFG supported Cluster of Excellence "Integrative Production Technology for High-Wage Countries". Firstly, an overall introduction to our current research in industry 4.0 research is given. After that we propose a conception of implementing digitalization and connection, which presents the effort to enhance both the ability of workers and human-machine-interaction in future production environment. Furthermore, we discuss the application areas of wearable computer technology and identify research topics for smart glasses. With a demonstrator developed in this scope for visual inspection of working parts we present the agile and flexible retrievability of information and interactivity of smart glasses in the future working environment. A further work area in our scope of Industry 4.0 development is the tracing & tracking of participating entities, i.e. the Internet-of-Things (IoT). We are now working on a Bluetooth-based agile low-cost Indoor Positioning System, which will also be proposed in this paper.*

**Keywords**: INDUSTRY 4.0, SMART DEVICES, VISUAL INSPECTION, INDOOR POSITIONING SYSTEM

## *1. Industry 4.0: The Future of Manufacturing*

The fourth industrial revolution (***Industrie 4.0***, Industry 4.0) is a by the German government proposed high-tech strategy to promote the manufacturing. The core components are Cyber Physical Production System (CPPS), Internet-of-Things (IoT), Cloud Computing and the predictive data analysis. By establishing "Smart Factories", Industrie 4.0 has the potential to raise global income levels and improve the quality of life for populations around the world [SCHW2016]. Similar initiatives can also be found worldwide, such as "Smart Manufacturing Leadership Coalition (SMLC) " and "Industrial Internet" in USA, "Made in China 2025" in China and "Industrial Value-Chain Initiative (IVI) " in Japan [HEI2016].

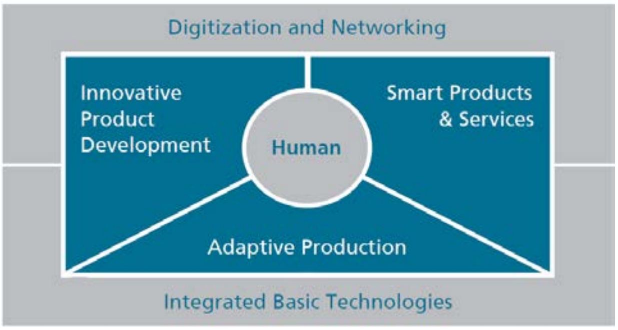


***Fig. 1:*** *Fraunhofer IPT's concept to implement Industrie 4.0 [IPT2016]*

At Fraunhofer IPT we are realizing industry 4.0 through ***human-centered adaptive digitalization and networking*** of machines, parts, personnel and other entities in the working environment. With analysis of big production data including machine states and product information gathered in the manufacturing, a predictive production process will be achieved, which leads to the reduction of raw materials and scrap parts and to shorten the makespan. In addition, smart devices will play a very important role to help people being integrated in the future manufacturing environment (***Fig. 1***).

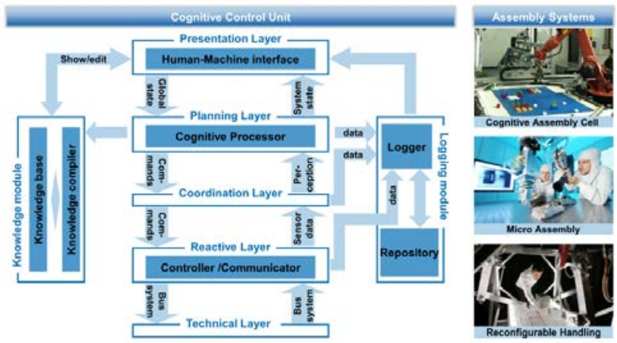


***Fig. 2:*** *"Cognition-enhanced, Self-Optimizing Assembly Systems" in CoE ICD D3 [RWTH2011]*

In the scope of the CoE ICD D3 the authors is currently working on the Industry 4.0 research and development. The Cluster of Excellences (CoEs) are by German Federal Ministry of Education and Research and German Research Foundation funded excellence initiative to promote cutting-edge research. At RWTH Aachen University, the challenge of the CoE "Integrative Production Technology for High-Wage Countries" is to (i) combine and enhance the results to a holistic theory of production while (ii) incorporating ecologic and social boundary conditions. The Goal of CoE ICD D3 – „Cognition-enhanced, Self-Optimizing Assembly Systems" is the concepts, models and tools for cognition-enhanced assembly and corresponding methods for self-optimization of highly automated assembly systems within a production network (***Fig. 2***).

## *2. Competence Enhancement using Smart Devices in Quality Control*

Diverse demonstrators have been developed in the scope of our research activities to present the advantages of Industry 4.0. In the coming section, a demonstrator to quicken visual inspection in turbine blade manufacturing the will be shown in this section.

This demonstrator shows how to enhance the personnel competence by using smart wearables and digital infrastructure platform in the future industrie 4.0 manufacturing environment. In this show case, we take a task of quality control in turbine blade manufacturing as an example.

Manufacturing of turbine blades is a extremely high-precision machining process, even though the quality assurance is a tough task and errors are difficult to avoid. Due to the high cost of materials (most of them use TiAl alloy), normally the defective blades must be repaired, e.g. through laser additive manufacturing. To detect the errors, a visual inspection of the blades in a mandatory task in the quality control process. Currently the visual inspection is done by a verification worker, he inspects the blades on a disk and saves the error description into computer or just on paper. In the next stage the reparation worker must locate these errors to repair them, if the description is not precise, usually it is a time-consuming job for him the find and classify the errors. With the technology advances of portable computers and smart wearables within the past decade, the workers can be enhanced with smart devices to deal with this task in an easier way. Our demonstrator presents how the digitalization, connection and smart devices can help to increase the productivity and efficiency in manufacturing process.


***Fig. 3:*** *Cloud-based visual inspection in quality control of turbine blade manufacturing using smart devices*

The demonstrator consists of three parts (***Fig. 3***):

- The verification staff marks the errors on the blade with a tablet pc and saves the error data (position, type, instruction etc.) into a cloud platform;
- The cloud platform provides access interfaces and storage via wireless communication technology (cellular network, wireless LAN or Bluetooth);
- The reparation staff locates the marked error with smart glasses, the marked errors will be reappeared exactly on these positions on the image of the real disk in the display of the smart glasses, as known as Augmented Reality (AR).

***Fig. 4:*** *Reappearance of the by verification staff with tablet marked errors on turbine blades in the display of smart glasses and other smart devices (Screen mirroring). The error markers will stay on the right place even when the smart devices move by tracking the QR code on the part.*

To be able to locate errors on the display in motion (the devices and the workers are obviously allowed to move), a technology is developed in which a QR code is used to implement optical tracking. The QR code is affixed on the turbine disk, and using the digital camera mounted on the smart devices the QR code can be tracked automatically using computer vision algorithm. Due to different optical parameters, a camera calibration process is done between devices to increase the precision of the camera tracking. The real picture of this demonstrator is shown in ***Fig. 4***. The third part of the demonstrator was developed with a ODG R-7 smart glasses on Android system.

## *3. Low-cost Indoor Positioning System*

One of our work areas in Industry 4.0 research is the localization of workers, parts, machines and all other entities in the working environment, which realizes an Internet-of-Things (IoT) platform. Following this thought, currently we are investigating the iBeacon technology, to implement a low-cost and agile solution.

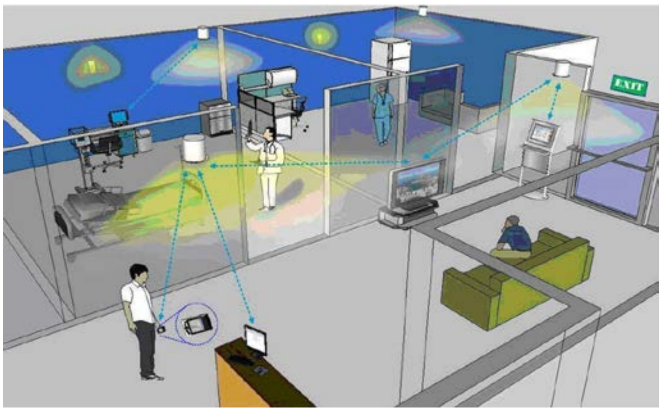

***Fig. 5:*** *Indoor Positioning (Image source: newsroom.ucr.edu)*

iBeacon uses small Bluetooth sensors, which emit Bluetooth signal in a fixed time interval. This signal will be received by smart devices with Bluetooth hardware (***Fig. 5.***). Due to the characteristics of electromagnetic waves, the signal will attenuate over the distance. Per the received signal strength from different distributed iBeacon sensors (at least) in mobile smart devices, the planar position can then be calculated through Trilateration.

One encountered problem at present is the enormous inaccuracy of the received signal, which was verified by several field experiments and fluctuates up to 100% of the signal strength (Fig. 6). To overcome this problem, we are currently investigating different time domain smoothing filters including Moving Average, Exponential Smoothing, Savitzky-Golay Filter, Kalman-Filter, etc. as well as Fuzzy Logic as possible solutions. Also, the Fingerprinting based searching pattern techniques [MEST2011] are in our consideration.

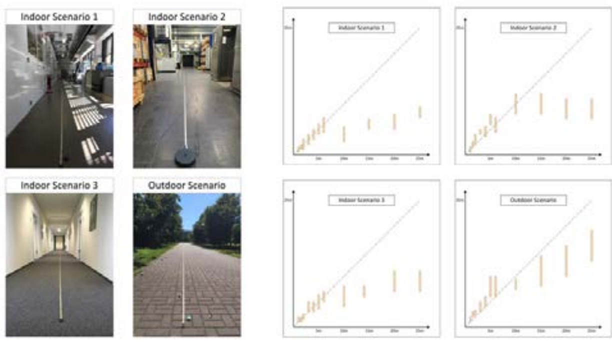


***Fig. 6:*** *Indoor Positioning (Image source: newsroom.ucr.edu)*

Another Challenge of the Indoor Positioning System is the failure safety of the sensor network due to the relative high amount of iBeacon sensors. There are various reasons, e.g. shielding by provisionally appearing foreign objects, battery failure, electromagnetic interference etc. To guarantee the Quality of Service (QoS) of the System, a Self-Optimizing mechanism will be needing in live operation, which bases on a cognitive monitoring of the sensor network.

Currently we are working on these two proposed challenges, the result will be published in a following paper.

## *4. Conclusion & Future Works*

In this paper, we presented our approach at Fraunhofer IPT to realize industry 4.0 through the adaptive digitalization and connection of machines, parts, personnel and other entities in the working environment. With this approach information and instruction will be available everywhere and all the time in the production process. Also, we presented a demonstrator for visual inspection in quality control of turbine blade manufacturing using smart devices, to show that with help of such smart devices the efficiency in the future working environment can be increased significantly. Furthermore, a running work area in our Industry 4.0 research, an Indoor Positioning System based on Bluetooth Low Energy technology, which enables an agile and low-cost implementation of the Internet of Things (IoT), was proposed.

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