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ORIGINAL PAPER

SMART SERVICES FOR ENHANCING PERSONAL COMPETENCE IN INDUSTRIE 4.0 DIGITAL FACTORY

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ABSTRACT. **Background:** Adaptive digitalization and networking of machines, working parts, employees and other entities on the plant floor are core of realizing industry 4.0, so that information and instruction will be available everywhere and all the time in the production process. Thus, smart devices, especially smart wearables, will play a very important role to help workers being integrated in the in the future manufacturing environment, as information need to be transferred faster and with the right level of detailing with respect to the individual need of workers, factory managers etc.

Methods: The implementation of an indoor localization system using Bluetooth beacons in the shop floor as part of an enterprise IoT platform was introduced. This sensor network is aimed to implement tracing and tracking of workers and working parts in the future smart factory, as well as the to the networking of the smart wearables with existing manufacturing machines. The investigated problem was the inaccuracy and the instability of the sensor signals by such Bluetooth sensor networks. To solve the problem, various algorithms were investigated.

Results and conclusions: The possible solution of given problem was solved by finding an algorithm improving the communication between devices. Together with the location information from Beacon network and orientation information from the compass sensor, it is able to determine the machine in the near, which the employee with the Smart Glasses is currently pointing to.

Key words: Industrie 4.0, industrial Internet-of-Things, indoor localization, smart wearables, augmented reality, enhancement of productivity.

INTRODUCTION

The fourth industrial revolution (Industry 4.0), proposed by the German government, is a high-tech strategy to improve competitive position by promoting manufacturing. The core components of Industry 4.0 include Cyber Physical Production System (CPPS), Internet-of-Things (IoT), Cloud Computing and 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 [Klaus 2016]. Similar initiatives worldwide include "Smart Manufacturing Leadership Coalition (SMLC)" and "Industrial Internet" in USA, "Made in China 2025" in China and "Industrial Value-Chain Initiative (IVI)" in Japan [Heilmann 2016].

Adaptive digitalization and networking of machines, parts, personnel and other entities in the working environment are the core of industry 4.0, with which information and instruction will be available everywhere and all the time in the production process. Thus, smart devices, especially smart wearables, will play a very important role to help employees

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integrating into the future manufacturing environment, as information need to be transferred faster and with the right level of detailing for individual needs of factory managers and other roles on the plant floor.

The Industrial Internet of Things (IIoT) is referred to as the networking of all participating physical entities in the production. By means of tracing and tracking working parts etc., IIoT monitors the supply chain and provides immense cost savings, giving manufacturing companies an opportunity to get their production line smarter [Möller 2016].

This paper starts by an overview of modern smart devices in production. After that, the indoor localization system based on Bluetooth Low Energy (BLE), which is currently being developed and deployed at Fraunhofer IPT, is introduced. Based on this indoor localization service, we developed a software demonstrator for Smart Glasses to show the potential for enhancing employee's competence in the production by using connected smart devices, which is descripted in this paper, too. At the end, a summary of the work and an outlook are given [Khan, Turowski 2016, Ismagilova et Al. 2017].

SMART WEARABLES IN MANUFACTURING

Smart Wearables or Wearables are portable microcomputers that are connected, equipped with diverse sensors, and can be worn on the body. To wearable devices belong smart glasses, watches, trackers, grooves, clothes etc. Wearables are different from other mobile devices, acting more like a body accessory to help inconspicuously than a communication partner, which one has to deal with seriously. Wearables are getting interesting both in consumer electric market like VR helms and in industrial field like head-mounted industrial smart glasses. According to industry survey, the global wearable technology market is expected to expand from US$ 750 million in 2012 to around US$ 5.8 billion in 2018, amount of device from 13 million in 2013 to 130 million in 2018 [Wei 2014].

Table 1. Comparison of mobile devices for our experience

	Laptop	Industrial Tablet	Smart Glasses
Performance	High	Medium	Low to Medium (SoC)
Information Presentation	High (Full Size Display)	Medium to High	Low to Medium (Restricted by Screen Size and Visibility)
Connectivity	High (Cellular, WiFi, Bluetooth, div. Interfaces and Sensors)	High (Cellular, WiFi, Bluetooth, div. Interfaces and Sensors)	Medium to High (WiFi, Bluetooth, div. Interfaces and Sensors)
Portability	Low	Medium to High (Partially Wearable)	High (Handsfree)
Service Time	2-10h	4-10h	2-3h
Human-Machine-Interaction	High (Keyboard, Mouse, Touch, Speech etc.)	High (Touch, Speech, Camera Optical Recognition)	Medium (Touch, Incompetent Speech Recognition, Weak Camera)

For manufacturing factories, the most striking feature of smart wearables is that they enable the hands-free information processing for employees at manufacturing workspace [Ballard, Brian 2017]. Most wearables devices are connected to a network, LAN or WAN, hence they become also part of the Internet of Things (IoT). Wearables devices are becoming more and more import on the plant floor, not only for helping employees finishing tasks, but also for motivating employees, in a way that they act like assistants, not replacement for employees. Furthermore, wearable technology is possible for collecting biometric data, which is useful for monitoring employee's health status.

Under all wearables, smart glasses is expected to be the most practical and powerful auxiliary equipment in manufacturing environment. Smart glasses process good portability, sensor technology, connectivity and operational handling, being able to provide information, instruction and tutorial on a head-mounted display while the employee can remain hands on the work. A detailed comparison of smart glasses with other mobile devices can be found in Table 1. In conjunction with Industrial Internet of Things and cloud-based smart manufacturing platform [Fraunhofer-Institut für Produktionstech-nologie IPT 2017], smart wearables can deliver revolutionary user experiences and great advantage to enhance the employee's competence in future digital factories.

CONNECTED PRODUCTION

The interconnection on plant floor is the fundament of digital factory. Machine-Human-Machine communication helps employees making quicker decisions, enabling reduction of confusion, easy transcription of manufacturing process, shop floor monitoring, keeping live production data always available, secure and up-to-date. Networking of machines, sensors, assets, business software, ERP/MES systems and other things makes enables to inspect the production processes holistically with various point of view. Big data analytics helps generating more information that is useful and gaining new knowledge, which makes it possible to optimize production processes and to create completely new business models.

In the scope of Industry 4.0, Internet-of-Things (IoT) is the vision of interconnection of all the entities in the physical world, so that they will always get in touch within the digital world. The term Industrial Internet of Things (IIoT) represents the industrial concept of an Internet of Things (IoT), in contrast to the consumption-oriented IoT concept. The Industrial IoT is a trend that, in addition to many other IT techniques, serves to improve operational efficiency. IIoT has been considered from the beginning as an effective approach to improve the supply chain and the value stream in a significant way. Furthermore, producing companies can also benefit greatly from IIoT by developing value-added application scenarios. From a visionary and application-oriented point of view, producing companies should be able to utilize IIoT to find new growth opportunities through three approaches: boost revenues by increasing production and creating new hybrid business models, exploit intelligent technologies and transform workforce [Accenture.com, 2017].

INDOOR LOCALIZATION

Indoor localization is an essential element of Industrial Internet of Things, which enables the tracing and tracking of entities in production environment, including employees, working parts etc. There are already several Implementations [infsoft GmbH 2014, Pointr Labs Limited 2016, Longo, Nicoletti, Padovano, 2017] of such indoor localization systems in the recent past. Possible application fields of Bluetooth-based indoor localization systems include store navigation, guided tour, and warehouse management, assist systems in airports, train stations and hospitals, etc.

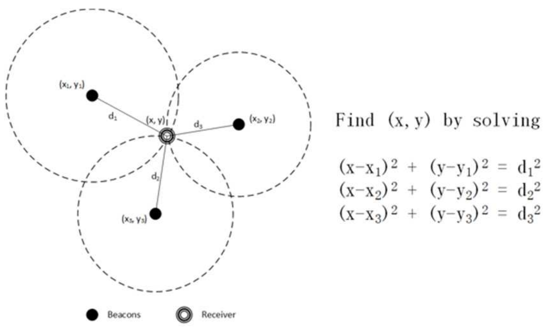

Fig. 1. A simplified scenario of determining receiver position through trilateration of measurable distances from three nearby Bluetooth beacons to a single receiver

The principle of Bluetooth based indoor localization is quite concise. The Beason sensors emit low-energy Bluetooth signals in certain short period, e.g. every one second. Within this sensor network, the distances between receiver devices to all detectable Beason sensors is to estimate through the received signal strength, respectively [Mautz

2008]. With at least three detectable Beacon sensors (assumed there are not distributed in a straight line) and the a priori knowledge of beacon positions, the position of the receiver can then be calculated by trilateration (Fig. 1).

The advantages of using this type of sensor are:

- Low-cost: Each Bluetooth beacon sensor costs around twenty Euro. Commercial indoor GPS systems start by several hundred thousand Dollars.
- High flexibility: There is no need to change any infrastructure for deploying this kind of sensor network.
- Low energy consumption: Based on the BLE technology, the replaceable button battery-driven beacon sensor has a service time of at least one year.
- High scalability: The horizontal scaling of the sensor network can be easily achieved by expanding with extra Beacon sensor. The position calculating algorithm on side of receiver devices will adapt to the new network topology automatically.

One discovered disadvantage of using BLE through our field experiment is its inaccuracy and the signal oscillation [Sun et. Al. 2016]. To improve the Quality of Service of this indoor localization system, we investigated diverse smoothing algorithms (moving average, exponential smoothing etc.) for stabilizing the received raw beacon signals, successfully [Sun et. Al. 2017] (The topic of signal stabilization is not covered in the present paper, for more information please refer to the references).

COMBINING SMART GLASSES AND INDOOR LOCALIZATION SERVICE

With these conveniences provided by modern technologies, it is quite mature and even necessary to improve the effectiveness of employees in the production, helping and motivating them adapting to the new industrial revolution. Here in this section, we show an example of combining these technologies.

For the fourth International Center for Turbomachinery Manufacturing, we have developed a software demonstrator combining smart glasses and the indoor localization service descripted in the last section (Fig. 2). A sensor network of Bluetooth beacons was deployed alongside an aisle of our machine hall with five meters to each other. Their absolute positions are stored locally in the Smart Glass as references.

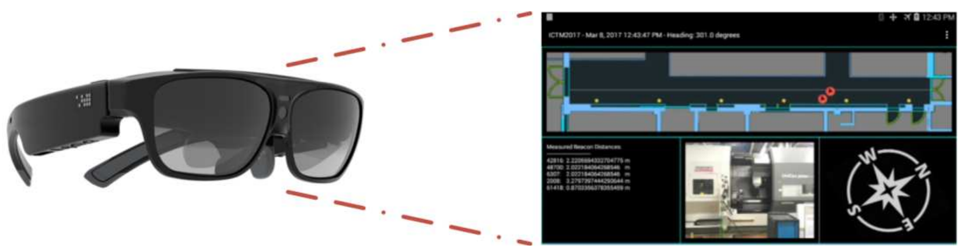

Fig. 2. Presentation of information with Smart Glasses (ODG R-7, real screenshot of Smart Glasses on right).

The GUI of the software demonstrator is depicted in Fig. 2. On the upper half an indoor map of the machine hall is depicted, on which the current position of the device is shown on the map. In addition, this position is updated every second. The position is calculated by smoothing of the raw data gathered from the built-in Bluetooth sensor. On the lower half, there are three parts. The left one holds a list of the raw data, i.e. the distances measured to all detectable Beason sensors. The part on the right is a digital compass getting the angle from the built-in magnetometer compass sensor. Together with the location information from Beacon network and orientation in-formation from the compass sensor, it is able to determine the machine in the near, which the employee with the Smart Glasses is currently pointing to. In the middle part of the lower half in the GUI, the live machine data can be shown. This represents an implementation of staff augmentation in Industrie 4.0 digital factories.

CONCLUSION AND OUTLOOK

In this work, we presented vision for future industry 4.0 digital factory and our approach to enhance competence of employees by using sound Smart Devices and indoor localization service. Smart Glasses process good portability, sensor technology, connectivity and operational handling, being able to provide information, instruction and tutorial on a head-mounted display while the employee can remain hands on the work. Indoor localization service locates object on the plant floor, enabling Industrial Internet-of-Things unobtrusively. By combining both, the employees are well equipped and motivated for dealing with tasks in future digital factories.

The next step in our scope of Internet-of-Things is the live connection between Smart Wearables and different machines and the real-time presentation of live machine data. Due to different types and ages of machines, it is hardly to define a uniform interface. To this end, we are working on the field of Smart Retrofitting [Guerreiro et. Al. 2017] in parallel, which is expected to help outdated machines integrating into future digital factories. The result will be presented in a coming paper.

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USŁUGI TYPU SMART SŁUŻACE ZWIĘKSZENIU KOMPETENCJI PERSONALNYCH W ZAKŁADZIE PRZEMYSŁOWYM TYPU INDUSTRIE 4.0

STRESZCZENIE. Wstęp: Zastosowanie sieciowych rozwiązań dla urządzeń i ich części, jak również jako wspomożenie dla pracowników na poziomie hali produkcyjnej jest podstawowym elementem wdrożenia Industry 4.0., dzięki czemu w każdym momencie i w każdym miejsce zapewnia się dostępność do potrzebnej informacji. W związku z tym, urządzenia mobilne typu smart będą odgrywały ważną rolę w integrowaniu pracowników w środowisko produkcyjne w przyszłości, informacja będzie mogła być przekazywana szybciej i z większą szczegółowością w odniesieniu do poszczególnych pracowników czy kadry zarządzającej.
Metody: Zastosowanie wewnętrznej lokalizacji przy użyciu Bluetooth beaconów na poziomie hali produkcyjnej jako fragmentu zakładowej platformy Internetu rzeczy zostało wdrożone. Sieć sensorów ma na celu śledzenie pracowników oraz urządzeń w przyszłościowym zakładzie produkcyjnym, jak również ma być połączeniem z istniejącym parkiem urządzeń produkcyjnych. Badany problem polegał na nietrafności i niestabilności sygnałów sensorów używanych w tej sieci. W celu rozwiązania problemu poddano analizie różne algorytmy możliwych rozwiązań.
Wyniki i wnioski: Znaleziono możliwe rozwiązanie analizowanego problem poprzez określenie odpowiedniego algorytmu poprawiającego komunikację pomiędzy urządzeniami. W połączeniu z lokalizacją informacji przy zastosowania sieci beaconów oraz zorientowaniu informacji pochodzących z sensorów, można było zlokalizować urządzenie znajdujące się w pobliżu danego pracownika przy użyciu okularów Smart Glasses.

Słowa kluczowe: Industrie 4.0, przemysłowy Internet rzeczy, lokalizacja wewnętrzna, nośniki smart, rozszerzona rzeczywistość, poprawa produktywności

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DIE SMART-DIENSTLEISTUNGEN UND DEREN BEDEUTUNG BEI DER ERHÖHUNG VON PERSONALKOMPETENZEN IM INDUSTRIE-UNTERNEHMEN VOM TYPE INDUSTRIE 4.0

ZUSAMMENFASSUNG. Einleitung: Die Inanspruchnahme von Netzwerk-Lösungen für die Einrichtungen und deren Teile, sowie die Unterstützung von Mitarbeitern in der Produktionshalle sind Grundelemente der innovativen Einführung von Industry 4.0., dank dessen in jedem Zeitpunkt und an jedem Ort der Zugriff auf die benötigten Informationen gewährleistet wird. Im Zusammenhang damit werden die Smart-Mobilgeräte in Zukunft eine wichtige Rolle bei der Integration der Mitarbeiter mit dem Produktionsumfeld spielen, wobei die Information wird schneller und präziser in Bezug auf die einzelnen Mitarbeiter oder Verwaltungskader weitergeleitet werden können.

Methoden: Es wurde die Anwendung der inneren Lokalisation bei der Inanspruchnahme von Bluetooth beacons in der Produktionshalle als dem Bestandteil der werkseigenen Plattform des Internets der Dinge eingeführt. Das Netzwerk von Sensoren bezweckt die Verfolgung der Mitarbeiter und Einrichtungen im zukünftigen Produktionsunternehmen und es soll ein Bindeglied mit dem bestehenden Maschinenpark werden. Das erforschte Problem beruhte auf fehlender Korrektheit und mangelnder Stabilität der in diesem Netzwerk eingesetzten Sensoren. Zwecks der Lösung des Problems wurden verschiedene Algorithmen für mögliche Lösungen einer Analyse unterzogen.

Ergebnisse und Fazit: Es wurde eine Lösung des analysierten Problems mittels der Festlegung eines entsprechenden, die Kommunikation zwischen den einzelnen Einrichtungen verbessernden Algorithmus gefunden. In Verbindung mit der Informationslokalisation und bei der Anwendung von Beacon-Netzwerken, sowie bei der Orientierung der von den Sensoren gewonnenen Informationen konnte die in der Nähe des betreffenden Mitarbeiters befindliche Vorrichtung unter Anwendung der Brille Smart Glasses lokalisiert werden.

Codewörter: Industrie 4.0, Industrie-Internet der Dinge, innere Lokalisation, Smart-Träger, verbreitete Wirklichkeit, Verbesserung der Produktivität

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