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Indoor location service in support of a smart manufacturing facility

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ABSTRACT

Location awareness in manufacturing facilities has high potential to produce information according to the space in which is important. This work presents a system that finds the nearest machine to a user. The system runs in an Android app which is part of a mobile enterprise resource planning system. The indoor localization system collects the received signal strength indicators (RSSIs) from low-cost Bluetooth beacons installed in the machines. The RSSIs are sent to the cloud which hosts the values and returns the name of the nearest machine. This work uses the fingerprinting algorithm to map the location of each machine with a set of four RSSIs. The results show the nearest neighbor, weighted k-nearest neighbor and Bayesian inference techniques, the latter presenting the best accuracy. Using the Kalman filter on the RSSIs reduces variability, which increases the correct machine coincidences. The use of one Bluetooth beacon per machine, guessed the correct machine around 89% of the time.

1. Introduction

One of the major recent revolutions in manufacturing is the capability to integrate the internet of things in the machine floor. With standards like MTConnect and other protocols (either based on request/response or publish/subscribe [1]), a huge amount of information can be acquired, stored and analyzed by using Cyber-Physical Systems [2]. The system can process the information remotely or in situ and can make it universally available. This availability in conjunction with the trend of Big Data, underscore the importance of having the right information, not only at the right time but also in the right place. That is why location awareness in the manufacturing field has a high potential to provide a way to discriminate information according to the space in which is more relevant.

The discussion about indoor localization encompasses applications in retail stores [3,4], health [5,6] and homes [7,8]. While indoor localization has huge importance in those applications, there is still the need to disclose the full potential and advantages that localization services can provide in manufacturing facilities. Gröger et al. [9] recognized the need to implement context and location awareness to provide workers with real-time information about the relevant processes in the manufacturing environment, as well as a way to reduce the effort while entering information. In their study, they implemented a tag-based localization, which needed the worker to scan QR-Codes positioned in key places with a mobile device. In a different approach, Huang et al. [10] implemented radio-frequency identification (RFID) detectors in machines and with them, located important assets in the machine floor. The system generated real-time information that fed the adaptive decision-making process. In a similar system that track materials on the shop floor using RFIDs [11], three main challenges were found that affect especially small and medium enterprises (SME). The challenges are high cost, lack of standards (high risk) and high technical threshold. From these studies, it is clear that the industry needs a functioning framework with indoor localization technologies and simple, low-cost solutions.

This work explores the advantages and challenges that indoor localization services can bring to the Internet of Manufacturing Things (IOMT). An environment of IOMT ensures access to reliable Wi-Fi and other radio frequency technologies, as well as the use of ubiquitous computing in combination with consumer electronics. A mesh of low-cost Bluetooth Low Energy (BLE) beacons (which are transmitters that help to find their position by broadcasting their identity) was installed in a small production volume machine floor. The Received Signal Strength Indicators (RSSIs) were used to locate the user in the space of the machines by the use of a mobile app developed by the research group. The mobile app is part of an open source Enterprise Resource Planning (ERP) system, which integrates information entered by the operator and provide the system with live updates. A diagram of the concept is presented in Fig. 1. This work specifically focuses on the details of the localization services achievable using a mobile device with Android operative system. The contribution of this project is to present a developed system in which a mobile application can detect machines in a

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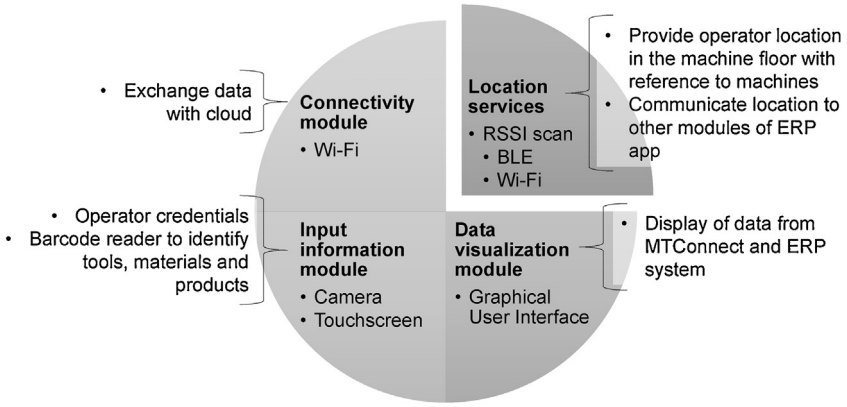

Fig. 1. Diagram of the concept of the mobile app for ERP and the comprising modules.

specific work area by installing some low-cost BLE beacons in the machines as shown in Fig. 2. This work analyses the accuracy of this system and provides the relationship of the accuracy of the system and the algorithm, the mobile device and the variability of the RSSIs. The concept shows how a mobile app with the BLE beacons has potential to navigate through the machine shop enabling the operator to input and display spatial information at each machine in real time. The objective is to eliminate the need for operator input, which can reduce the possibility of human error. It can also serve as a flag to display current machines critical parameters.

This paper is organized as follows. Section 2 briefly describes related work on various indoor localization technologies. Section 3 explains the algorithm for the indoor localization. Section 4 provides details on the indoor localization setup. In Section 5 the mobile app architecture and its integration with cloud computing is presented. Section 6 presents the results and the interpretation of the results. Finally, in Section 7, concluding remarks are given.

2. Related work

Determining location, whether indoors or outdoors, can be done in a number of ways. For example, the most popular outdoor tracking system is Global Positioning System (GPS) which is a satellite-based navigation system to give absolute coordinates of a mobile node. GPS are well known to be used exclusively in outdoor applications [12]. Indoor localization has been studied widely in the academic landscape. Analyzing the state of the art by technology, Bluetooth Low Energy (BLE), Wi-Fi, RFID, and vision are among the most viable solutions. Vision-based indoor localization usually relies on beacons and pattern recognition and has the potential to provide high accuracy [13], however, it requires high amounts of computational resources, special cameras and the right conditions of light and visibility in order to operate [7]. In indoor tracking, radio frequency beacons have been used in systems such as Active Badge Location system [14] and the *Cricket System* [15]. Similarly, RFID technology is used in

Fig. 2. Cutting machines with the BLE beacons (red circles) on them (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).