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Design and implementation of a low cost RFID track and trace system in a learning factory

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Abstract

The factories of the future will make use of actuators, sensors and cyber-physical systems (CPS) to provide an environment in which human beings, machines, and resources will communicate as in a social network. In such a network, communication between various "objects" relay the current state of the physical world. Business decisions are made using the information and it is therefore critical that this information is accurate and in real-time. Information flow is a key enabler of such future factories. Industrial engineers, as designers and improvement agents of such factories of the future, will need to develop better skills in various aspects of data analytics and information communication technologies. This paper describes the development and implementation of a low cost RFID track and trace system (by students) for application in a Learning Factory for teaching undergraduate industrial engineering students key concepts related to Industry 4.0 and "smart factories". The benefit of this system is not only a demonstrator to be used in the Learning Factory, but also can be used to teach students in a "learning by doing" fashion critical skills related to real time tracking in a manufacturing environment. The system also demonstrates potential low cost implementation of such technologies in SME's.

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Keywords: RFID; Track and Trace; Industry 4.0; Learning Factories

1. Introduction

Today we stand on the cusp of the Fourth Industrial Revolution, one which promises to marry the worlds of production and network connectivity in an "Internet of Things" [1]. No longer do machines just produce products, the

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products communicate with the machine to tell it exactly what to [1]. Key elements of this fourth industrial revolution (or Industrie 4.0 as coined by Germany) include the digitization and real-time-oriented integration of the various components of the value-adding system [2]. Hermann [3] set out to provide a clear definition of Industry 4.0 based on a comprehensive literature review. He defines Industry 4.0 as follows: "Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industry 4.0, cyber physical system (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT (Internet of Things), CPS communicate and cooperate with each other and humans in real time. Via the IoS (Internet of Services), both internal and cross- organizational services are offered and utilized by participants of the value chain." This definition mentions the four major components of Industry 4.0: CPS, IoT, IoS and Smart Factories. CPS enables the fusion of the virtual world with the physical world [4]. IoT allows things and objects, such as RFID tags, sensors, actuators, mobile phones etc to communicate and interact within a smart factory [5]. The idea behind the IoS is to use the internet for new ways of value creation in the service sector [6]. A key enabler of the CPS, IoT, IoS and Smart Factories is cloud computing, which is also transforming the conventional product-oriented manufacturing business model into a service-oriented one [7]. The requirement for mass customization under Industrie 4.0 however brings significant complexity, which makes the design and evaluation of product-service systems challenging [8].

RFID has been identified as an important technology for enabling the real-time-oriented integration/communication of the various components of the value-adding system in an Industry 4.0 context [9]. This paper describes the development and implementation of a low cost RFID track and trace system (by students) for application in a Learning Factory for teaching undergraduate industrial engineering students key concepts related to Industry 4.0 and "smart factories". The benefit of this system is not only a demonstrator to be used in the Learning Factory, but also can be used to teach students in a "learning by doing" fashion critical skills related to real time tracking in a manufacturing environment. The system also demonstrates potential low cost implementation of such technologies in small-and-medium sized enterprises (SME's).

2. Track and trace technologies

Tracking and tracing are important concepts in global supply chain and logistics networks [10]. Two key technologies being used in supply chain environment for tracking and tracing are barcodes and Radio-frequency identification (RFID). RFID is a modern automatic identification and data capture (AIDC) technology that is slowly gaining more acceptance in the supply chain today. RFID technology allows objects to be identified without line of sight and with a greater reading distance compared to barcode technology [11], [12]. RFID tags can hold much more data and support a much larger set of unique IDs than barcodes [13]. In addition, RFID systems can discern many tags in a single area at once without human assistance, unlike their barcode counter parts. For electronic track and trace technology to compete with traditional barcode technology they must either be equally as cheap or add enough value to an organization to recover the cost elsewhere [14]. The main reason RFID technology is becoming more popular, has been its drastic decrease in price over the years. With the technology reaching a critical point which could see its larger scale adoption in the consumer retail section [14].

According to, Sarma et al. [15], all RFID systems are comprised of three components: the tag or transponder, the reader, as well as the data processing subsystem comprising of middle-ware and internal databases. Tags at the highest level, can be divided into two classes namely active and passive tags. Active tags have power a source integrated into the tag and actively send a Radio Frequency (RF) signal to communicate with the RFID reader. Passive tags on the other hand are powered through interrogation signals from the reader and communicate through either near or far field communication [15].

Each RFID system operates at a given frequency range. This frequency range determines the system's capabilities and limitations. Consequently, the higher the frequency range the shorter the wavelength, the harder it becomes for the RF to pass over obstacles and reach the receiver. In other words, the higher the frequency, the higher the interference. The radio spectrum is part of the electromagnetic spectrum from 3Hz to 3000GHz. Therefore, the different types of tags can be placed into three distinct frequency ranges: Low Frequency, High Frequency, and Ultra High Frequency tags (these depend on the country).