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An intelligent value stream-based approach to collaboration of food traceability cyber physical system by fog computing

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ABSTRACT

Good advanced food traceability systems help to minimize unsafe or poor quality products in food supply chain through value-based process. From the emerging technologies forthcoming for industry automation, future advanced food traceability system must consider not only cyber physical system (CPS) and fog computing but also value-added business in food supply chain. Accordingly, this study presents a novel intelligent value stream-based food traceability cyber physical system approach integrated with enterprise architectures, EPCglobal and value stream mapping method by fog computing network for traceability collaborative efficiency. Furthermore, the proposed intelligent approach explores distributive and central traceable stream mechanism in assessing the most critical traceable events for tracking and tracing process. Successful case study, software system design and implementation demonstrated the performance of the proposed approach. Furthermore, experiment shows the better results obtained after the simulation execution for intelligent predictive algorithm.

1. Introduction

. Over the last decade, food traceability has become popular recognized method for food manufacturing management. Good food traceability systems help to minimize unsafe or poor quality products in food supply chain through value-based process. Such value-based process should focus on collaboration of traceability activities with food logistics and technological aspects for food traceability efficiency. Therefore, value-based food traceability is applied as a tool to assist in the assurance of food safety and quality to meet consumer satisfaction. In food traceability, it consists of two modules including tracking and tracing. Tracking aims to understand and control the downstream path of a product for following ability along the supply chain. Tracing aims to obtain and link the upstream records of the origin and characteristics of a particular product such as species, country/fishing area, production method for referring ability along the supply chain. However, these tracking and tracing information during food supply chain such as transport and processing of meat food are often lost and inaccurate due to lack of advanced computerized system to control traceability efficiency. From the advanced computerized system perspective, food traceability cyber physical system (CPS) is emerging internet of thing (IoT) system. Accordingly, this article adopts value stream mapping (VSM) method to explore of valued-added and highly flexible food traceability cyber physical system for collaboration efficiency. The value stream mapping was described to implement multiple flow value stream mapping that merge in case of a complex product (Khaswala & Irani, 2001) and applied lean manufacturing principles (Abdulmalek & Rajgopal, 2006). In order to enable the CPS to collaborate each other, a visualization of processes needs to be generated by VSM that is a reconfigurable tool for the visualization of processes. Mendes, Leitão, Colombo, and Restivo (2012) presented reconfigurable manufacturing systems based on service oriented system. Furthermore, resource integration plays important role in the industrial revolution of the fourth industrial revolution raising collaboration productivity by CPS which embed some resources such as computers, sensors and robots into an integrated platform, especially food traceability. The drawback of prior industry automation is the overall lack of integration resource and cannot be easily retrofitted and reconfigurable across downstream and upstream companies. That means that tracked and traced mechanism of food integrated resources refers to the collaboration ability to follow the downstream path of a product and to determine the upstream origin and characteristics records in the food supply chain (Bechini, Cimino, Marcelloni, & Tomasi, 2008). Thus, today's industry automation do not only meet the requirements concerning horizontal and vertical business

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integration, but also adopt an advanced software and hardware implementation. Accordingly, this article proposes industrial resource planning (IRP) information system to enable collaboration productivity using EPCglobal as resources integration platform in accordance with the food traceability cyber physical system. From the IRP concept, it is crucial to develop system architecture for intelligent system such as CPS. Prior literature reviews had been discussed in such system architecture research for CPS and service-oriented architecture. Lai, Ma, Chang, Chao, and Huang (2011) proposed an OSGi-based service architecture for Cyber-Physical Home Control Systems. Chen, Zhang, and Wang (2015) proposed integrated open geospatial web service-enabled cyber-physical infrastructure using service-oriented architecture middleware between heterogeneous physical sensors for precision agriculture monitoring. However, a few studies presented a variety of business and customer services applied CPS from the business strategy that drives the information system such as Enterprise Architectures (EA) (Zachman, 1987) and TOGAF (TOGAF, 2011). EA is a method that aligns functional business into high-level view of an organization's information-related integration of services to understand the relationship and the interaction between these services components for allowing enterprises to meet the needs of rapidly changing environments with business agility, scalability, flexibility, availability and utilization of services on demand. This article adopts enterprise architectures to food traceability cyber physical system with industrial services components virtualized by a web service embedded into intelligent object such as automation device. In such cyber physical system, it is based on cloud computing network. But cloud computing network can hardly satisfy cold chain requirements such as mobility support, location awareness and low latency, so this article explores fog computing network. No study has yet been published that considers the fog computing-based food traceability.

To sum up the above-mentioned discussion, an increasing food traceability efficiency in enhancing CPS-based food manufacturing benefit with architecture-based intelligent system has prompted food quality research that focuses on the importance of the food traceability efficiency. In a word, this study accordingly presents a novel intelligent value stream-based food cyber physical system approach with EA, EPCglobal and VSM method by fog computing network for traceability collaborative efficiency. It aimed at optimizing complex CPS-based food traceability system with collaborative mechanism while quantifying the efficiency impact of food manufacturing benefit in food supply chain.

This paper is organized as follows: Section 2 introduces related work such as food traceability system, EPCglobal, EA and VSM. Section 3 presents the proposed approach to develop novel intelligent value stream-based food cyber physical system approach with EA, EPCglobal and VSM method by fog computing network. It consists of distributive and central traceable stream mechanism. Section 4 presents the case study for agriculture food product in this approach including information system design architecture of intelligent CPS-based food traceability system. Section 5 presents software implementation for CPS-based food traceable system using UML state chart and SOAP API technology. Section 6 explores experiment of numerical example for intelligent predictive algorithm, Section 7 concludes the work and future research.

2. Related work

2.1. Food traceability system

This article studies and summaries related literature reviews for food traceability in Table 1 and appendix. Literature reviews in Table 1 illustrate both food traceability and related method or technology. Generally speaking, they could be divided into two areas. One is theme of traditional food traceability management system. The other is contribution of research. Theme of food traceability describes mainly a concept of controlling and monitoring of supply chain processes. From Table 1, it is valued as an important aspect of safety, quality and sustainability in the food industry which was explored by information system, food information, consumer demand for food traceability efficiency.

2.2. Cyber physical system

A CPS is computational operation with the surrounding physical object across downstream/upstream industry in collaboration environment. Its capability comprises a network of physically distributed sorts of device/machine embedded sensors and equipped with computing system. A CPS can communicate to seamlessly connect and remotely control production processes, information services available over the internet of things (IoT) and cloud computing. By these advanced technologies, Cyber-Physical Systems can produce intelligent computation such as autonomous predictive management, self-diagnosis/maintenance mechanism and collaborative production planning for business performance. Thus, CPS is intelligent systems that act as the agents by autonomous learning human-being behaviors with the help of artificial intelligence (Feigenbaum, 1982). Intelligent system is an intelligent program that solves a difficult problem. Intelligent systems use a human-expert knowledge in order to resolve problem (Hayes-Roth, 1984; Huang, Chen, Kuo, & Jeng, 2008). This article applies CPS-based intelligent systems into food traceability system that can be considered as a self-configurable capable of performing a variety of tasks by triggered traceable event using intelligent algorithms without human instructions in advance. For this purpose, intelligent products may be defined as physical and virtual objects with unique ID using RFID technology in CPS system.

In the food manufacturing, Cyber-Physical Systems mainly consists of three modules such as field device process, production machine process and manufacturing control process using service-oriented architecture to handle. Thus, CPS-based food manufacturing includes all the elements having industrial automation capabilities including smart PLC (programmable logic controllers), sensors, actuators, cameras, vehicles, robots, radars, control units for the subsystems, wired/wireless sensor networks, machine vision/motion control such as automated optical inspection, IPv6, RFID, Micro Electro Mechanical Systems (MEMS) and advanced control technologies for SCADA (supervisory control and data acquisition). From the above-mentioned saying, CPS-based food manufacturing is very complex and heterogeneous systems comprising multiple types of physical systems and multiple models of computation and communication. CPS-based food manufacturing system consists of three layers such as physical layer deeply embedded cyber capabilities in physical entitles processes, network layer for getting stronger cyber and service layer which contains lots of distributed operation services.

2.3. Enterprise architecture

Today, it is major question that each company focus on capabilities of individual enterprises traditionally in a dynamically changing business environment. Each company should explore the enterprise integration perspective that core competitiveness in the industry comes from the capability of integrated value chains across supply chain (Panetto, Ricardo, & Arturo, 2012). From this perspective, the objective of value chains is to streamline end-to-end more comprehensive and accurate information to the enterprises. In food supply chain, current consumers especially focus on