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Autonomous tracing system for backward design in food supply chain

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ABSTRACT

Food safety and quality issues generally occur due to incurring problem of food products handling processing. It led to a growing interest in developing systems for food supply chain traceability. At present, there are lacking in modeling the traceability process for developing “autonomous” traceability system in comparative to “automation” and little research has been conducted where the product problem information related to the cause of problem, the responsibility attribution simultaneously. This paper design the autonomous agent-based tracing system based on IoT (internet of things) architecture using FCM (fuzzy cognitive maps) and fuzzy rule method for product usage life cycle. The case study for agriculture *food product is discussed.* It aimed to simulating food tracing complex system with imprecise relationships while quantifying the performance impact of backward design process efficiency using the total effects algorithm.

1. Introduction

Customers all over the world have required various food safety and health issues in the past years. Food safety and quality issues generally occur due to incurring problem of food products handling processing. The concerns about food safety and quality have launched new legislative initiatives along the food supply chain (FSC). These factors have led to a growing interest in developing systems for food supply chain traceability. The increasing interest directly produces with customer demands on food quality and safety in food traceability (Trienekens & Zuurbier, 2008). However, the benefits have been categorized as: increase in customer satisfaction, improvement in food crises management, and improvement in FSC competence development (for companies), technological and scientific contribution and contribution to agricultural sustainability (Bosona & Gebresenbet, 2013). A FSC consists of several stakeholders among each other such as farmers, producers, processors, distributors, retailers. FSC stakeholders typically attribute different values to traceability: for the customer it represents a food needs related mainly to safety and quality, while for food producers it control food production visibility which might strongly affect the product quality.

Traceability in the whole supply chain is the capability of the stakeholders to tracking and tracing the products throughout the supply chain in a forward and/or backward direction. Tracking is the ability to follow the downstream path of a product along the supply chain in a forward. Tracing refers to the ability to determine upstream path of the origin and characteristics of a particular product in a backward (Bechini, Cimino, Marcelloni, & Tomasi, 2008). Tracing is the reverse process of tracking by which the history of a product in food supply chain is aim to identifying problem through food product usage life cycle for food safety and quality issues. A FSC traceability system is considered as a record-keeping and task-triggering mechanism to improve consumer confidence in food consumption and to efficiently reduce the asymmetry of information across food supply chains. Research into traceability systems covers some topics such as traceability system development (Feng, Fu, Wang, Xu, & Zhang, 2013). Some studies proposed to aim at facilitating data acquisition for the development of databases and web-based systems for traceability management (Gandino, Montrucchio, Rebaudengo, & Sanchez, 2009; Ruiz-Garcia, Steinberger, & Rothmund, 2010). Traceability systems required to comply with all stakeholders needs can yield a huge volume of information, therefore information technologies (IT) with data collection, storage and accessibility become critical.

In recent years, a great research interest about integrating RFID (radio-frequency identification) and EPCglobal (electronic product code) within the food supply chain has emerged (Kumar, Reinitz, Simunovic, Sandeep, & Franzon, 2009; Myhre, Netland, & Vevle, 2009). Pizzuti, Mirabelli, Sanz-Bobi, and Gomez-Gonzalez (2014) presents the Food Track &Trace Ontology (FTTO) which is part of a general framework devoted to managing food traceability and it has been developed a global track &trace Information System.

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Thakur, Sorensen, Bjornson, Foras, and Hurburgh (2011) introduces a new methodology for modeling traceability information using the EPCIS (EPC information system) framework and UML (unified modeling language). Kang and Lee (2013) propose and develop a novel set of services called the traceability services using EPCglobal information system. Lin et al. (2011) proposed a WSN-based (wireless sensor network) traceability system for aquaculture that can automate many monitoring tasks. Based on the requirements of traceability in the food chain, a conceptual framework is explored (Aung & Chang, 2014). Alfredo, Alvarez-Melcon, Trebar, and Filippin (2014) presents a novel system based on the EPCglobal Architecture and developed under the framework "RFID from Farm to Fork" in the aquaculture sector.

According to the above-mentioned discussion, this article indicates two issues. Firstly, the focuses of these studies tend to be on automated identification and product problem status in food chain based on internet of thing (IoT) using new technology such as RFID, WSN and EPCglobal, there is lacking in modeling the traceability process for developing "autonomous" traceability system in comparative to "automation". Secondly, little research has been conducted where the product problem information related to the cause of problem, the responsibility attribution and their effect on the food quality and safety is recorded simultaneously. Each FSC actor should have an autonomous triggered behavior that would enable them to trace back from backward product design so as to determine the cause of the problem or to efficiently attribute the responsibility. The development and design for a food product is the most important issue in a competitive market. The forward design is the key on the R&D department. Which a new product is successful or fail, is related to the customer product problems. So we can trace the problem and clarify the responsibility for efficient performance management. We can accumulate experience and feedback to design origin so that mechanisms such as design guidelines/checklist can be developed to prevent problem reoccurrences in the future. This is a thought which establish a reverse design by reverse thinking (Youngsup & Russell, 1995).

The food product problems here may be extended to farmers, producers, processors, distributors, retailers and customer. When a food product occur problems, it is usually a customer brings up the problem and gives the product to the retailer for handling. Normally, the food product will be sent to the original retailer which is a chain retail store, and then the original retailer will send it to distributors to trace. If the distributor cannot handle this problem, it will be sent to the producers or processors. This process is a long, complicated and not efficient. However, they usually don't have an efficient way to utilize the past information well within the tracing and longwinded flow path. So that when the problem occurs next time, they will spend much time on the handling and tracing for the problem again. In order to solve the two issues, it is important to develop IoT-enabled autonomous systems for food chain traceability through upstream supply chain and provide an integrated framework of backward design process seamless and relationship in the product usage life cycle. This upstream supply chain includes linking units of output with specific units of input for all stakeholders.

As the IoT techniques become intelligence, emphasis is put upon approaches that allow things to become more autonomous. The existence of a large number of variables to be considered for FSC traceability to trace the cause of problem and the responsibility attribution, due to the additional variables relating to the stakeholders, and the uncertainty imposed on the variables require collaborative judgment to identify core variables and the causal relationships among them. For such situations, fuzzy cognitive maps (FCM) seem to be appropriate to deal with and model complex system (Stylios & Groumpos, 2001). We propose the utilization of the fuzzy causal characteristics of FCM and fuzzy rule-based knowledge repository as the underlying approach in order to generate a hierarchical and dynamic network of interaction performance impact. By using the above mentioned approach, this paper design the intelligent autonomous tracing system based on IoT architecture using FCM and fuzzy rule method for food product usage life cycle. It aimed at simulate complex system with imprecise relationships while quantifying the performance impact of backward design process efficiency.

This paper is organized as follows: Section 2 introduces related work such as IoT, FCM, intelligent system and software agent. Section 3 presents the proposed approach to develop intelligent autonomous tracing system for backward design in food supply chain. Section 4 describes the autonomous Tracing FCM by state-transition method. Section 5 presents the case study for agriculture *food product.* Section 6 submits experiments that are conducted by utilizing numerical analysis of FCM conduct total effects algorithm in the case study. Section 7 concludes the work and future research.

2. Related work

2.1. Internet of things

With the advent of information system and related emerging technology, such as IOT (Internet of Things) is available in the Market. The internet of things attributed to the Auto-Id Labs (2010) is a novel paradigm that refers to the possibility of endowing everyday objects with the ability to identify and interact with each other to reach cooperation goals (Giusto, Iera, Morabito, & Atzori, 2010). The IoT describes a global network infrastructure, internet-based information service architecture around us of a variety of things (objects)-such as RFID tag, sensors, readers, actuators, mobile phone, NFC etc. Internet of things is as an infrastructure to facilitate the information exchange of products (Amaral et al., 2011; Atzori, Iera, & Morabito, 2010). The technical development of the required infrastructure of components is specified by EPCglobal (2013). EPCGlobal architecture is a set of internet of things objects and information exchange standard implemented by the international organization "EPCGlobal", it defines the information exchange units such as basic form standard, middleware, EPCIS and advanced applications, discovery service and pedigree, to integrate into this architecture. Mobile RFID system had focused on practical application. The past researches represent solving the quality tracing system for quality control in supply chain (Zhang, Ran, & Ren, 2011). The quality tracing is traceability capability that it can find the source of food product problem and identify of the inputs used and production operations to trace the history of product through the supply chain to or from the place and time of production (Manos & Manikas, 2010; Resende & Hurley, 2012).

At present, tracing system has some application in electric product recalling and food production pedigree The role of WSN (wireless sensor network) in the IoT is that of a virtual skin by becoming aware of their surroundings to take informed decisions in industrial environments. EPCglobal allows for sharing of information related to product problem integrated of RFID technology into the EPC standard. The conceptual sensor data integration has been exploited the classification approach (Theodorou, 2007).

2.2. Intelligent system and software agent

Taking into account different possible intelligent system, a autonomous mechanism can be considered as a self-created behavior capable of performing a variety of tasks by triggered event using intelligent algorithms based on condition without command