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Achieving quality assurance functionality in the food industry using a hybrid case-based reasoning and fuzzy logic approach

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ABSTRACT

Quality control of food inventories in the warehouse is complex as well as challenging due to the fact that food can easily deteriorate. Currently, this difficult storage problem is managed mostly by using a human dependent quality assurance and decision making process. This has however, occasionally led to unimaginative, arduous and inconsistent decisions due to the injection of subjective human intervention into the process. Therefore, it could be said that current practice is not powerful enough to support high-quality inventory management. In this paper, the development of an integrative prototype decision support system, namely, Intelligent Food Quality Assurance System (IFQAS) is described which will assist the process by automating the human based decision making process in the quality control of food storage. The system, which is composed of a Case-based Reasoning (CBR) engine and a Fuzzy rule-based Reasoning (FBR) engine, starts with the receipt of incoming food inventory. With the CBR engine, certain quality assurance operations can be suggested based on the attributes of the food received. Further of this, the FBR engine can make suggestions on the optimal storage conditions of inventory by systematically evaluating the food conditions when the food is receiving. With the assistance of the system, a holistic monitoring in quality control of the receiving operations and the storage conditions of the food in the warehouse can be performed. It provides consistent and systematic Quality Assurance Guidelines for quality control which leads to improvement in the level of customer satisfaction and minimization of the defective rate.

1. Introduction

Food quality is an important issue in the food industry. Lots of quality checking and assurance duties are required throughout the whole food chain. Poor quality control decisions may lead to a high level of defective goods and a poor level of customer satisfaction (Nilsson, Johnson, & Gustafsson, 2001; Youngdahl & Kellogg, 1997). Currently, food safety assuring systems like Hazard Analysis and the Critical Control Point (HACCP) system are widely promoted for demonstrating the commitment to food safety in the food industry (Orriss & Whitehead, 2000). The warehouse, where food is stored and where value adding activities are performed, is no exception to this commitment. In order to ensure the food is of acceptable quality, appropriate quality control actions need to be performed (Getinet, Seyoum, & Woldetsadik, 2008; Yan, Sousa-Gallagher, & Oliveira, 2008). However, the operations and duties that need to be undertaken for the sake of safety assurance are complex and difficult to apply.

In fact, the current quality assurance process adopted in warehouses has several serious problems. Traditionally, the decision making process for selecting the necessitate quality control operation relies mainly on the skills and experience of operators. This means that errors can easily occur. Nevertheless, the increasing niche requirements of diversified value added activities and the great variance in Stock Keeping Unit (SKU) which require entirely different handling operations in the warehouse, further increase the complexity of the quality control. On top of this, numerous researchers have undertaken different studies in promoting and evaluating the importance of adopting various quality assurance systems concerned with food handling. However, the actual practical automation of a quality control assistance system in warehouses, as a research field, has not yet been much explored. An investigation into the adoption of a decision support system (DSS) for automating the process may help to improve the situation.

The purpose of this paper is to outline and illustrate a decision support approach to automate the existing human based decision making practice for determining the appropriate quality assurance operations for food inventory management. An integrative prototype system, namely, the Intelligent Food Quality Assurance System (IFQAS), has been developed, not only for facilitating the selection of the most appropriate quality control operations, but also for suggesting the best storage environment for the goods after the quality

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has been checked. In the system, a Case-based Reasoning (CBR) engine which solves new cases by reusing the previous handling experience in decision making is proposed to replace the manual decision making patterns in deciding the quality assurance operations. Because of the special nature of the food items it is not possible for humans to judge accurately the condition of the food inventory or express the conditions in precise numerical values, so often vague, fuzzy logic techniques are applied in order to extract the critical quality assurance information in terms of fuzzy rules. Therefore, a Fuzzy rule-based Reasoning (FBR) engine is constructed for suggesting the appropriate storage environment.

The rest of this paper is organized as follows. In Section 2, the current quality assurance method used in the food industry with the application of various kinds of technology is reviewed. In Section 3, the system architecture of an Intelligent Food Quality Assurance System (IFQAS) and the mechanism of its two modules are described and explained in detail. In Section 4, a case study for validating the feasibility of the adoption of IFQAS is presented. Section 5 contains a detailed discussion of the system's performance. The final section, Section 6, concludes the paper.

2. Related works

Deterioration in food quality may lead to a huge impact on the credibility of a food company (Shapton & Shapton, 1991) and products that have been subjected to a compromise of different conditions and sensory properties would affect customer's choice and preference during purchasing (Perrot et al., 2004). Now, there is a movement afoot to change the current human-judgment based food quality control approach to a more scientific and systematic one. When the quality and conditions of food are solely interpreted by the human operators, errors occur easily (Perrot et al., 2006). Human based quality assurance or decision making can manage the operations, but are believed to be unimaginative and arduous and lead to inconsistent actions (Davidson, Ryks, & Chu, 2001). Therefore, solely relying on human observation and evaluation is not systematic or reliable enough. This indicates that implementing quality assurance or control measurement is a critical issue. Researchers have explored this issue, however, it was found that their emphasis was on the importance of implementing such assurance system (Blaha, 1999), investigating the relationship between factors, such as the consequence of poor quality, the quality culture and the effectiveness of the goals achieved and the activities which lead to its adoption, (Karipidis, Athanassiadis, Aggelopoulos, & Giompliakis, 2009), and the provision of an implementation plan (Asefa et al., 2011). Researchers rarely evaluated the decision making process used for selecting the appropriate quality control operation procedures for particular types of food.

In addition to this, researchers have adopted different DSS when undertaking quality control operations. Deslandres and Pierreval (1997) have designed a knowledge advisory system for quality applications; a quality advisory model is built for structuring the knowledge required for quality problem solving. Carpenter and Maropoulos (2000) have developed a system called OPTIMUM for controlling the tool machining process. It makes use of a combination of mathematical modeling and rule-based statistical methods for decision making. Shaffer and Brodahl (1998) have proposed a rule-based management system for offering management solutions for maintaining better farming conditions. Their predefined rules are stored in a database for decision making.

However, those systems lack the self-learning capability of being able to procure human being's knowledge. In handling food related operations, the decision making process involves numerous adjustments, therefore, self-learning and improving are important. As it has this special skill it is believed that Case-based Reasoning (CBR) is probably the right choice. CBR is one of the most popular techniques for solving problems in the selection of operations. Peng, Chen, Wu, Xin, and Jing (2011) have developed a virtual reality based integrated system, applying CBR for matching the most similar machining fixture design case from a case-based database. It helps assign the production operations in the designing of parts. Kalapanidas and Avouris (2001) have proposed a NEMO prototype for improving the quality of air in operating conditions. It combines heuristic and statistical techniques based on the CBR approach for suggesting solutions. Chow, Choy, Lee, and Lau (2006) have applies CBR for selecting the most suitable resource usage package for handling warehouse operations. It found that using CBR engine for suggesting the operations is time saving and cost effective. Xia and Rao (1999) adopted CBR technology in an operation support system. The implementation result pointed out that CBR helps achieve more consistent and accurate operations. It found that there has been a trend to adopt learning techniques which use cases or instances directly, such as in Case-based Reasoning (CBR) (Kim, Im, & Park, 2010). In general, it is believed that CBR is particularly suitable for solving problems of domains that are experience-rich but knowledge poor (Chi, Chen, & Kiang, 1993). Nevertheless, the CBR techniques may only be capable of handling the decision making process at the operations selection level, but it may not be applicable for solving problems in food handling such as monitoring storage conditions. To reach a high-quality level and identify errors in operations, attention should be paid to all of the characteristics of the sub-processes (Guillaume & Charnomordic, 2001). Probably, a system which can provide an all-round quality assurance support down to the parameter level is required.

With reference to the published studies, Pacella and Semeraro (2005) applied Artificial Neural Networks (ANN) to the management of quality control in manufacturing processes. It recalled the learning patterns from the incomplete representations in order to monitor the quality characteristics. The system helps detect, classify and predict any unnatural changes that occur in the manufacturing process. Bezerra et al. (2007) have used ANN for data classification and pattern recognition for predicting material behavior for quality prediction. Jung and Yum (2011) have proposed an ANN-based approach for mapping the relationship between the characteristics, design and signals for taguchi parameter design.

However, ANN need their inputs to be expressed in numeric terms for the decision making to process (Metaxiotis, Ergazakis, Samouilidis, & Psarras, 2003), the relationship between the status and the condition of the food items as the storage environment evaluation is complex and difficult to describe through modeling. Instead of using modeling, tackling this relationship using fuzzy logic approach is a probable solution. Fuzzy logic provides a methodology that managing blurry attributes and allow the use of data and information from those who possess expert knowledge. It has become an increasing important approach for tackling food problems and handles human reasoning in linguistic terms (Guillaume & Charnomordic, 2001). It is found that fuzzy logic techniques have been widely used in managing food problems. Researchers (Ioannou, Perrot, Curt, Mauris, & Trystram, 2004; Lababidi & Baker, 2003; Perrot et al., 2004) have adopted the fuzzy logic in assisting the quality control of food items during the production process. It is found that the concept and terms describing the quality of food items, and the justifications in the human mind are in an area of uncertainty and vagueness. Therefore, it is difficult to adjust and make decisions based on the measurement results in terms of numbering and crisp values. Fuzzy logic is considered as a tool that is suitable for dealing with fuzzy relationships, criteria and phenomena (Amelia, Wahab, & Hassan, 2009; Lin & Hsieh, 2004). Applying fuzzy terms in decision making, helps capture the reasoning process or the hidden uncertainty of operations (Jiang & Chen, 2005). Hence, the development of fuzzy sets helps build the linkage between words and numbers.