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Development of an intelligent quality management system using fuzzy association rules

H.C.W. Lau [a,*], G.T.S. Ho [a], K.F. Chu [a], William Ho [b], C.K.M. Lee [c]

[a] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hunghom, Hong Kong
[b] Operations and Information Management Group, Aston Business School, Aston University, Birmingham B4 7ET, United Kingdom
[c] Division of Systems and Engineering Management, School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore

Abstract

In order to survive in the increasingly customer-oriented marketplace, continuous quality improvement marks the fastest growing quality organization's success. In recent years, attention has been focused on intelligent systems which have shown great promise in supporting quality control. However, only a small number of the currently used systems are reported to be operating effectively because they are designed to maintain a quality level within the specified process, rather than to focus on cooperation within the production workflow.

This paper proposes an intelligent system with a newly designed algorithm and the universal process data exchange standard to overcome the challenges of demanding customers who seek high-quality and low-cost products. The intelligent quality management system is equipped with the "distributed process mining" feature to provide all levels of employees with the ability to understand the relationships between processes, especially when any aspect of the process is going to degrade or fail. An example of generalized fuzzy association rules are applied in manufacturing sector to demonstrate how the proposed iterative process mining algorithm finds the relationships between distributed process parameters and the presence of quality problems.

Keywords: Production quality; Quality improvement; Quality information system

1. Introduction

High-quality and high-reliability products play an important role in achieving customer satisfaction, and insisting on quality is always the only way for an enterprise to survive. In fact, to achieve high-quality is not the responsibility of any one person or functional area; it is everyone's duty in the entire corporation. Poor process decisions from any individual may lead to poor customer satisfaction. The ultimate goal is to achieve better collaboration for making right decisions all the time in every process involved. Although numerous empirical and scientific approaches have been developed in the field of quality management, past research has not addressed this issue well enough, nor has actual practice managed to optimize the integrated workflow in order to make sure that all the participants have the possibility to act successfully in their processes. Traditionally, various functional disciplines have had their own information systems for quality control and monitoring in their own specific process. However, the fact that quality improvement is a distributed and cooperative problem-solving activity has been neglected. Therefore, attention should be paid to capturing the distributed process data to support knowledge discovery within the workflow of the enterprise.

The purpose of this paper is to present a methodology for discovering the hidden relationships among all the process variables involved in a distributed and automatic manner. The iterative Process Mining (i-PM) algorithm based on the concept of fuzzy set and association rule method is proposed to extract interesting patterns in terms

* Corresponding author. Tel.: +852 2766 6628; fax: +852 2362 5267.
E-mail address: mfhenry@inet.polyu.edu.hk (H.C.W. Lau).

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of fuzzy rules, from centralized process data stored as quantitative values. An intelligent prototype system called the Intelligent Quality Management System (IQMS) has also been developed to support knowledge discovery within the workflow of the enterprise. This paper is divided into four main sections. Section two is a literature review conducted on existing quality improvement methods adopted in the industries by different kinds of intelligent systems, knowledge discovery technologies and the data exchange standard. The basic algorithm and the architectural structure of IQMS are described with the detailed explanation of two main modules in Sections 3 and 4. Final section concludes the entire paper by presenting the key findings and future work.

2. Literature review

In order to survive in the increasingly customer-oriented marketplace, exceeding customer expectations marks the fastest growing quality contributing to an organization's success. Most of the customers do not mind paying a little bit more for a higher quality product. Therefore, in a free enterprise system, it is necessary to improve quality and reduce manufacturing cost on a continuous basis (Dehnad, 1989). All of an organization's activities can be described by processes and are characterized by having a large number of differing, but interdependent process sections and many complex influential factors (Bernardy & Scherff, 1998). Common process characteristics include the input; the activities performed using the input, and the output. Processes that are important to an organization are usually controlled. Such control may be attained by supervision and maintenance and review of records (Heinloth, 2001). Having the concept of Total Quality Management (TQM) in mind, it is possible to develop an intelligent system to capture quality audit data from different processes during manufacturing so as to discover meaningful patterns and knowledge for future improvement (Ho, Lau, Lee, Ip, & Pun, 2006). A critical aspect of planning for quality improvement is to discover the relationship between process features and quality features or results automatically. Some data mining and artificial intelligence technologies have been shown to contribute to this and are highly effective in addressing many engineering solutions. Sterjovski, Nolan, Carpenter, and Norrish (2005) introduced back-propagation neural network models which can predict the mechanical properties of steels in various applications. Abburi and Dixit (2006) adopted the hybrid approach of ANN and fuzzy set theory for the prediction of surface roughness in the turning process. A Genetic Neural Fuzzy System (GNFS) with the hybrid learning strategy was developed to construct a quality prediction model for the injection of process from the input and output data (Li, Jia, & Yu, 2002). Lou and Huang (2003) stated that decision making of quality control can be performed by a fuzzy MIN–MAX algorithm for heuristic knowledge and optimization for fundamental knowledge, which is particularly useful for process engineers to identify the possible solutions for defect reduction.

Association rule, one of the data mining technologies has been widely used to support industrial quality improvement nowadays. An Association Rule Mining System (ARMS) is proposed by Jiao and Zhang (2005) for effective product portfolio identification. Chen, Tseng, and Wang (2005) proposed the Root-cause Machine Identifier (RMI) method using the technique of association rule mining for analyzing correlations between combinations of machines and the defective products. Liu and Ke (2007) adopted the technique of association rule to discover decision making and dependency knowledge on a production line. The discovered situation/action profiles and knowledge patterns are used to construct a knowledge support network, which forms the basis of support for solving problems on a production line.

Quality improvement has got a number of effective AI and data mining techniques with a wide range of applicability. Since there are a lot of techniques available, there are many options for quality engineers to select appropriate techniques in different areas. Nevertheless, this situation poses difficulties as to the correct use of the different techniques, since most of such techniques have their own capabilities and yield results valid only within specified objectives. The need for choosing the most adequate technique for this research shows that it is necessary to coordinate the vastly distributed process data in an integrated manner and conduct a correlation analysis between process parameters and finished quality for continual quality improvement. The challenge is to develop more sophisticated techniques that can assist quality or process engineers in analyzing distributed process data easily and quickly so as to streamline the integrated workflow within the enterprise.

In summary, there are a number of approaches and systems, which have been designed and implemented to achieve continual quality improvement. First, there is a lack of literature on the intelligent system in process management for enhancing quality in a cooperative and distributed manner. In this research, the i-PM algorithm is developed based on the concept of fuzzy generalized mining algorithm proposed by Hong, Lin, and Wang (2003). It supports knowledge discovery and decision support from a large amount of process data by finding different parameter combinations to achieve desired finished quality.

3. Infrastructure of the Intelligent Quality Management System

The IQMS is designed to capture the distributed process data from different processes within the integrated workflow and convert the data into knowledge in terms of fuzzy association rules along the workflow which have positive or negative impacts on the quality of the finished products. In fact, it also allows process or quality engineers to access an object-oriented repository to retrieve the updated current