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A slippery genetic algorithm-based process mining system for achieving better quality assurance in the garment industry

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ABSTRACT

Due to the error-prone nature of garment manufacturing operations, it is challenging to guarantee the quality of garments. Previous research has been done to apply fuzzy association rule mining to determine process settings for improving the garment quality. The relationship between process parameters and the finished quality is represented in terms of rules. This paper enhances the application by encoding the rules into variable-length chromosomes for optimization with the use of a novel genetic algorithm (GA), namely the slippery genetic algorithm (sGA). Inspired by the biological slippage phenomenon in DNA replication, sGA allows changes to the chromosome lengths by insertion and deletion. During rule optimization, different parameters can be inserted to or removed from a rule, increasing the diversity of the solutions. In this paper, a slippery genetic algorithm-based process mining system (sGAPMS) is developed to optimize fuzzy rules with the aim of facilitating a comprehensive quality assurance scheme in the garment industry. The significance of this paper includes the development of a novel variable-length GA mechanism and the hybridization of fuzzy association rule mining and variable-length GAs. Though the capability of conventional GA in rule optimization has been proven, the diversity in the population is inherently limited by the fixed chromosome length. Motivated by this phenomenon, the sGA suggested in this paper allows various parameters to be considered in a rule, improving the diversity of the solutions. A case study is conducted in a garment manufacturing company to evaluate the sGAPMS. The results illustrate that better quality assurance can be achieved after rule optimization.

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1. Introduction

In view of improved standards of living, customers nowadays are having higher expectations on products during purchasing. To remain competitive in the market, manufacturers are urged to improve their product quality while at the same time to lower the costs and increase the speed to market. Nevertheless, there is a common trade-off between product quality and production efficiency. Some manufacturers tend to increase the production efficiency to meet the demand, causing adverse impacts on the resultant product quality. On the contrary, some manufacturers, especially those in labor-intensive industries, think that they have to sacrifice production efficiency if they attempt to guarantee the product quality. Such a trade-off phenomenon plagues many industries, in particular, the garment industry as it is an experience-rich industry with relative low technological capabilities. Most decisions involved in the garment industry are determined based on human experience, without a clear-cut theory to determine what production parameters should be used to optimize both efficiency and product quality. Without any knowledge support tools, there are no standardized approaches for monitoring the production processes while having product quality taken into consideration. This has attracted many researchers to apply the use of data mining and artificial intelligence techniques in order to discover knowledge to support decision making in garment production. Previous research has described the use of fuzzy association rule mining (FARM) for determining appropriate process parameters for quality assurance (Lee, Ho, Choy, & Pang, 2014). The knowledge discovered was, however, mainly based on the occurrence of frequent patterns. As a consequence, parameters having rare associations are usually not considered, nor included, in the rules.

In addition, genetic algorithms (GAs) have been applied to hybridize FARM for optimization. In traditional GAs, the length of the chromosomes is fixed, depending on the parameters appearing in the set of rules. The rules obtained in FARM usually serve as the initial population. Considering that parameters having rare associations are not considered during optimization, the diversity in the population and the knowledge discovered is inherently limited. This paper

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makes an attempt to use a novel GA mechanism, namely the slippery genetic algorithm (sGA), to overcome this limitation. The proposed slippery genetic algorithm-based process mining system (sGAPMS) allows changes to the chromosome length by insertion and deletion. Consequently, different combinations of parameters can be considered in a fuzzy rule, increasing the diversity of solutions. The knowledge discovered in the rules in this paper is used to support quality assurance in the garment industry.

Previous research work has shown that the use of Boolean association rule mining is promising for the formulation of effective Quality Improvement (QI) strategies in the garment industry (Lee et al., 2013). With the use of Boolean association rule mining, product defects appearing in the rules showed no relationships with the parameters settings used in the production. This could be a drawback as one of the critical aspects of QI planning is to discover relationships between the process parameters and the product quality (Lau, Ho, Chu, Ho, & Lee, 2009). On the other hand, considering that decision making in production always requires consideration of various uncertainties (Azadeganm, Porobic, Ghazinoory, Samouei, & Kheirkhah, 2011; Petrovic & Duenas, 2006), it is more convenient for operators to describe the process parameters by using natural language such as "low" and "high", instead of using quantitative values of the parameters. Since there are always no clear-out theories to judge whether a particular process parameter is "very low", "low", "high" or "very high", it is important to take the fuzziness of data into consideration when discovering the relationships between the process parameters and the product quality. In this paper, attempts are made to hybridize fuzzy set concepts with association rule mining to diagnose the quality problems at the parameter level. The fuzzy association rules obtained represent knowledge in fuzzy linguistic terms which are easily understandable by human beings and can provide direct knowledge support for quality assurance.

This study is a continuing work, based on our recent research, which applied FARM for quality assurance in the garment industry (see Lee et al., 2014). The proposed sGAPMS in this paper acts as an enhancement of the Radio Frequency Identification-based Recursive Process Mining System (RFID-RPMS) described in Lee et al. (2014) by optimizing the rules. This paper is a pioneer work in imitating and transcribing the biological slippage into GAs. The aim is to propose a new scheme of variable-length GAs to overcome limitations caused by fixed-length GAs with an objective of enhancing garment quality. The contributions of this paper include a novel GA framework with slippage concepts, an integration of GA and FARM specifically in the garment industry, and a more comprehensive quality assurance scheme supported by the hybridization of artificial intelligence (AI) techniques. A dataset collected in a garment manufacturing company has been used to test the proposed system and compare the results with that of using a rule mining system without the sGA. By so doing, the advantages brought by the sGA in achieving better garment quality are confirmed.

2. Literature review

In today's customer-oriented market, QI of products has become a critical task in the manufacturing industry. Since QI requires analysis of data (Köksal, Batmaz, & Testik, 2011), many researchers have applied data mining and artificial intelligence (AI) techniques to perform QI activities. Association is a popular data mining technique to identify groups of items that occur together from datasets, and the knowledge discovered is in the form of IF-THEN rules. The Boolean association rule mining problem over basket data was firstly introduced in Agrawal and Srikant (1994). Two stages are involved in the algorithm (i) to find the frequent itemsets, and (ii) to use the frequent itemsets to generate association rules (Alatas, Akin, & Karci, 2008). However, in real-world applications, the data concerned are usually not Boolean, but numeric (Chen, Hong, & Tseng, 2009). Furthermore, in the manufacturing industry, it is common that numeric data contain uncertainties or vagueness which could arise from market demand, capacity availability, process times, and costs (Aliev, Fazlollahi, Guirimov, & Aliev, 2007; Martín, Rosete, & Fdez, 2014; Mula, Poler, & Garcia-Sabater, 2007). In this sense, fuzzy association rule mining (FARM) is more meaningful than Boolean association rule mining especially for application in the manufacturing industry.

Compared with other manufacturing industries, the garment industry is more complicated in nature as it consists of various machines, workers and thousands of bundles of cutting pieces producing different styles simultaneously (Gunesoglu & Meric, 2007). In addition, quality inspection of garments is performed manually (Wong, Yuen, Fan, Chan, & Fung, 2009; Yuen, Wong, Qian, Chan, & Fung, 2009). Without any mechanisms for analyzing the hidden correlations between quality problems, defect prediction and defect diagnosis cannot be carried out effectively, causing failure in achieving QI (Lee et al., 2013). Therefore, an attempt should be made to investigate the capability of FARM in providing the garment industry with knowledge support for achieving better garment quality.

Previous research has been done to apply FARM to help garment manufacturers understand the relationship between parameter settings and finished quality (Lee et al., 2014). The results showed that FARM is capable of capturing process parameters and quality features of products to support knowledge discovery for quality assurance. In the abovementioned work, the data considered were expressed in linguistic terms, such as "medium" and "high", in the rules. These rules are useful in the development of a fuzzy rule base for the application of fuzzy logic. If they are of good quality, the results of the fuzzy logic can be greatly enhanced (Tahera, Ibrahim, & Lochert, 2008). In view of this, integrating fuzzy set concepts with genetic algorithms (GAs) has become an active research area to generate an optimal set of fuzzy rules and membership functions (Ho et al., 2008; Lau, Tang, Ho, & Chan, 2009; Wang, Hong, & Tseng, 2000). However, recent researches show that the applications of GAs in the manufacturing sector mainly focus on scheduling of production orders (Ishikawa, Kubota, & Horio, 2015; Jun & Park, 2015; Rahman, Sarker, & Essam, 2015; Zhang, Ong, & Nee, 2015), and logistics operations during or after production (Joo & Kim, 2014; Mohtashami, 2015; Pramanik, Jana, Mondal, & Maiti, 2015). GA applications focusing on QI of products have been scarce. In view of this, one of the highlighted contributions of this paper is that GA is applied to refine the rules for improving the product quality in the garment industry.

GA operates based on the principles of genetics and natural selection in which crossover and mutation are the two basic operators. A possible solution for a given problem in GA is called an individual or a chromosome. The crossover operator generates two offspring (new candidate solutions) by recombining the information from two parents, followed by the mutation operator in order to perform a random alteration of some values in a chromosome (Juang, 2004). Wang et al. (2000) applied GA to the integration of multiple fuzzy rules sets. If some features were not used in individual rules, dummies would be inserted into the rules to ensure that all chromosomes were of the same length. In addition, Lau, Tang et al. (2009) used GA to generate an optimal or nearly optimal fuzzy set and membership functions for the process parameters. After the domain knowledge was represented with a fuzzy rule set, the obtained fuzzy rules and the associated memberships were encoded into chromosomes. Each chromosome represented one fuzzy rule and the related problem. Through the crossover and mutation operations, an optimal or nearly optimal fuzzy set and membership functions for the process parameters were discovered. Furthermore, Chen et al. (2009) integrated GA and the fuzzy concepts to discover suitable minimum supports, membership functions and useful fuzzy association rules from historical transactions. Each chromosome in the population represented a possible minimum support and membership functions for an item. The chromosomes in the same

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