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Application of intelligent data management in resource allocation for effective operation of manufacturing systems

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ABSTRACT

Resource allocation has been a critical issue in manufacturing. This paper presents an intelligent data management induced resource allocation system (RAS) which aims at providing effective and timely decision making for resource allocation. This sophisticated system is comprised of product materials, people, information, control and supporting function for the effectiveness in production. The said system incorporates a Database Management System (DBMS) and fuzzy logic to analyze data for intelligent decision making, and Radio Frequency Identification (RFID) for result verification. Numerical data from diverse sources are managed in the DBMS and used for resource allocation determination by using fuzzy logic. The output, representing the essential resources level for production, is then verified with reference to the resource utilization status captured by RFID. The effectiveness of the developed system is verified with a case study carried out in a Hong Kong-based garment manufacturing company. Results show that data gathering before resource allocation determination is more efficient with the use of developed system where the resource allocation decision parameters in the centralize database are effectively determined by using fuzzy logic. Decision makers such as production managers are allowed to determine resource allocation in a standardized approach in a more efficient way. The system also incorporates RFID with Artificial Intelligence techniques for result verification and knowledge refinement. Therefore, fuzzy logic results of resource allocation can be more responsive and adaptive to the actual production situation by refining the fuzzy rules with reference to the RFID-captured data.

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1. Introduction

There are several important manufacturing industries in Hong Kong such as the electronics industry, the watches and clocks industry, the toy industry, and the garment industry. Though the economy of Hong Kong is now dominated by the service sector, the manufacturing sector still makes an important contribution to the economy as it generates substantial demand for inputs from the service sectors [1]. Owing to the need for higher efficiency, shorter product life cycle, better product quality and higher customer satisfaction, production planning plays a critical role in manufacturing [2,3]. Production usually involves the participation of more than one individual unit, each performing different functions in the overall production system [4]. Therefore, production planning problems involve determining the amount of resources to be assigned and allocated to all individual units so that each of them can complete its jobs. Effective resource allocation has been called a means to increase productivity by providing efficient usage of limited resources [5,6]. Thus, it is widely accepted as an important factor for gaining competitiveness in the dynamic market. This paper presents a resource allocation system (RAS) induced by an intelligent data management approach, with the aim to provide effective and timely decision making for operations related to resource allocation.

The rationale for selecting the Hong Kong garment industry for the verification of the RAS is that it is generally more time-sensitive than other manufacturing industries. Most of its manufacturing activities are geared to the needs of overseas markets [7], where there is currently a popular concept of "fast fashion" which aims to design and manufacture fashion products quickly and economically. An enhancement of the effectiveness and efficiency of the decision making processes involved in resource allocation is thus of great importance for survival in fast fashion.

This paper is organized as follows. Section 2 presents a literature review related to this study. Section 3 describes the architecture of

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the RAS. Section 4 presents a case study where the RAS is developed and implemented in a garment manufacturing company. Section 5 contains results and discussion of the system. Section 6 presents the conclusion and the future work.

2. Literature review

2.1. Resource allocation

Due to the intense competition in the global market, manufacturers who fail to efficiently allocate and utilize their resources will eventually lose their competitiveness [8]. Numerous benefits brought by effective resource allocation include efficient usage of resources, successful promotion of business performance, optimizing companies' objectives and achieving goals [6,9,10]. This has aroused the interest of many researchers who have investigated various approaches for resource allocation management, such as linear programming [11–13], simulation [14–16] and genetic algorithms [17–19]. However, these approaches no longer meet the challenges in today's manufacturing industries. Firstly, with the increasing technological innovation, the market demand is more unpredictable and the product life cycle has been reduced [20–23]. Existing approaches the operation of which is based on historical data or estimations are not flexible enough to deal with the increasingly dynamic market. Besides, more product options have to be given to customers resulting from mass customization [24], thus increasing the scale and complexity of resource allocation problems in production. However, such large-scale resource allocation problems are often mathematically intractable [25] which make current mathematical approaches not suitable, while other approaches like simulation can only cover a limited number of conditions [26]. Thirdly, conventional quantitative approaches may not be capable of dealing with the actual resource allocation problems in industrial manufacturing environments where most decisions inherently face imprecision and uncertainties [27–29]. Owing to the above highlighted reasons, a more sophisticated approach in resource allocation is a necessity for the survival in the manufacturing sector.

2.2. Fuzzy logic and DBMS

In manufacturing, uncertainties or vagueness could arise from market demand, capacity availability, process times, and costs [30,31]. It is more convenient for the management or decision makers to use subjective judgment and linguistic terms such as "high" and "very high" to describe imprecision [32–35]. Fuzzy logic, one of the Artificial Intelligence (AI) techniques, is a good candidate to deal with uncertain and vague manufacturing variables [36–38]. Fuzzy sets are used to represent linguistic terms and to develop relationships between input and output variables [39–41]. Therefore, many researchers have applied fuzzy logic to solve production planning problems in which linguistic terms are very effective in decision making. Díaz et al. [42] incorporated fuzzy approaches to manage the production priority in roll shop departments in the steel industry. Petrovic and Duenas [43] presented a fuzzy logic based system for production scheduling in the presence of uncertain disruptions. As scheduling involves the allocation of resources to tasks in order to complete those tasks within a reasonable amount of time [16,44,45], many resource allocation problems are addressed during the investigation of production scheduling. There has also been extensive discussion in the literature about the applications of fuzzy logic in manufacturing industries.

To improve information retrieval, fuzzy logic or fuzzy set theory has been introduced into databases for several decades [46]. This involves the concept of Database Management System (DBMS) which is a complex multi-attribute tool used for data processing and supporting different types of business applications with the use of a database [47,48]. Morales et al. [49] proposed a system which stores information in a DBMS that can support the mechanism of fuzzy set theory. Rodrigue et al. [50] designed a fuzzy database which stores imprecise information in a DBMS. In a similar vein, Zhang et al. [51] included both fuzzy and non-fuzzy attributes in their fuzzy databases. While fuzzy data can be handled and managed in a database, the database can also act as a fact-base and so the fuzzy system searches the database when a fact is required [52]. However, there are no standardized approaches incorporating fuzzy logic and DBMS for handling vague decision variables in resource allocation.

There are three different approaches for a fuzzy system to interact with a DBMS [52]. The first one is to incorporate extended data management facilities into the fuzzy system while the second one is to embed deductive rules into DBMS resulting in an intelligent database. The third one is to have both the fuzzy system and DBMS as independent systems with some form of communication between them. Considering that it may not be always practical to construct a new DBMS before one can use it, the third interaction approach is more applicable for designing a generic system for resource allocation as it allows the use of an existing independent DBMS. In such a case, data analysis for resource allocation can be done by an independent fuzzy system after retrieving data from the DBMS.

2.3. Monitoring of resource allocation

After resource allocation, resource utilization can be selected for measurement as it is one of the important factors reflecting the productivity of a production system [9]. Data related to the utilization of resources in one period must not affect the capacity of resources in other periods [53]. This underlines the fact that resource utilization has to be traced over time and be measured dynamically. Radio Frequency Identification (RFID) is widely accepted as a means to enhance data handling processes [54,55] and is able to capture dynamic data [56]. Thus, RFID could be a possible solution for measuring resource utilization.

There are researches applying RFID in manufacturing industries, most of which aimed at keeping track of production processes. Ngai et al. [57] implemented an RFID-based manufacturing management system in a garment factory where RFID tags were associated with a bundle of cut-raw materials while RFID readers were installed next to each sewing machine to keep track of the production process. Zhong et al. [58] presented an RFID-enabled real-time manufacturing execution system which deployed RFID devices on the shop-floor to track and trace manufacturing objects and collect real-time production data for planning, scheduling, execution and control. On the other hand, with the use of RFID technology, a manufacturing planning and control system proposed by Wang and Lin [59] is capable of performing three main functions, which are (i) the timely generation of an accountable production and operation schedule, (ii) active monitoring, control and execution of shop floor operations, and (iii) real-time evaluation of production performance. Although RFID technology can have a positive impact on manufacturing by improving productivity, increasing flexibility in production planning and control, enabling products to be customized, improving change-over management, improving tracking and utilization of reusable assets, higher visibility and accuracy of real-time data, strengthening customer relationships and, most importantly, facilitating effective resource allocation [60–65], many of its applications in manufacturing remain to be explored [66] such as its coordination of the resource management process [67].

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