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Applying multi-agent technique in multi-section flexible manufacturing system

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ABSTRACT

In the highly competitive market, cooperative multi-agent transaction and negotiation mechanism have become an important research topic. This paper uses multi-agent technology to construct a multi-section flexible manufacturing system (FMS) model, and utilizes simulation to build a manufacturing environment based on JADE framework for multi-agent to combine with dispatching rules, such as shortest imminent processing time (SIPT), first come first serve (FCFS) earliest due date (EDD), and Buffer Sequence. This paper finds that using multi-agent technique for multi-section FMS model can enhance the production efficiency in practice. Meanwhile, in this study, multi-agent systems combined with dynamic dispatching can be used to identify the best dispatching rules combination for achieving largest throughput, and thus it can provide the reference for production scheduling in advance.

1. Introduction

With the increasingly diversified market demands for small batch production, customized manufacturing mode must be employed so that the production system, production line and procedures can be adjusted flexibly to manufacture various kinds of products. Flexible manufacturing system (FMS) is an automated production mode most suitable for the aforementioned requirements, and has been valued in the manufacturing industry. It incorporates advanced computer application systems, such as Material Requirement Planning (MRP), Group Technology (GT), Computer Aided Process Planning (CAPP) and Multi-Processing Planning, ranging from ordering and material processing to delivery under system monitoring and resource assignment. This process is planned comprehensively to shorten the processing time and saving the cost.

With the recent advancement of information technology, Artificial Intelligence (AI) has been developed prosperously, so multi-agent technology has attention of researchers. The concept of agent has been applied to FMS, and the resource allocation for the manufacturing system is analyzed and discussed through the negotiation, coordination and cooperation mechanism among agents. In Smith (1980) proposed a multi-agent system – Contract Net Protocol (CNP), for resolving the contest of resources in a cooperative manner. This is a commonly-used coordination mode whereby the agents can resolve the resource allocation through negotiation and coordination based on Contract Net Protocol. Although there have been many researches focus on applying multi-agent technique on FMS. However, to the best of our knowledge, there is no literature of applying multi-agent technique on multi-section FMS.

This paper applies multi-agent technology to multi-section FMS controller design, in order to build an agent-based control mode to improve the availability of machines, shorten the manufacturing time and increase the capacity. The objectives of this paper are to build a multi-agent based FMS cell controller via software agent technology, and to find the best dispatching rules combination for achieving largest throughput in a real case of multi-section FMS.

2. Literature review

2.1. Flexible manufacturing system

The concept of FMS, originated from London-based Molins, was proposed by its R&D engineer David Williamson in early 1960s, and named as System24 (24 h operation, of which including 16 automatic operation) in 1965 for patent claims. The purpose of FMS is to satisfy the customer requirements for diversified and sophisticated products, and meet the expectations of the enterprises such as: shortening the delivery period, improving the quality and reducing the cost. Hence, FMS was planned for adapting itself to the aforementioned requirements as well as the production systems with medium and small throughput (Groover, 2001; Maleki, 1991). According to Nagarjuna, Mahesh, and Rajagopal (2006) and Viswanadham and Narahari (1992), FMS is defined as an integrated computer-controlled configuration, including: CNC machines, auxiliary production equipments and automated material handling system, with the purpose of medium and small batch production of a variety of products. Thus, FMS can manufacture diversified parts in a cost-effective way while minimizing the temporary inventory.

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FMS aims at improving the product quality, reducing the production cost and shortening the lead time (Deng & Yang, 1999). As a real-time production system, FMS incorporates several CNC machines, material handling system and warehousing system, of which the computer of higher hierarchy is used for automatic monitoring. The communication mode between the cell controllers within FMS and other machines (e.g. RGV, CNC machine, Loading/Unloading station), proposed by Deng and Yang (1999), is illustrated in Fig. 1.

As for the hardware infrastructure of FMS, every independent machine is provided with a PLC for controlling its process; then, individual PLCs on the machines are connected to a master PLC, which is then linked to main computer via RS232 or RJ-45 (networked). Thus, the main computer can monitor the real-time status of every machine by reading the buffer of master PLC. Similarly, the main computer can also send message or command to various PLCs for performing the subsequent actions, or send the parameters and NC programs of machines via network. Thus, the coordination and control of FMS are assigned by main computer, and there is no signal communication among the machines and equipments, ensuring more simple and rapid control and operation of FMS.

2.2. Agent technology

With the rapid development of e-commerce today, IT and Internet services are incorporated into many enterprise operations. In such case, artificial intelligence is developing quickly, of which the concept of intelligent agent has become a key example of today's software development. The agents along with agent technology are widely discussed and applied in various fields. Stuart and Norvig (1995) suggested that, agent is defined to provide any service for other individuals or substances after authorization. An agent should set its target and act intelligently in an actual environment (Stone & Veloso, 2000). Agent should receive the external or internal commands, and handle the messages or tasks received through pre-established knowledge mechanism (Moore, Reyns, Kumara, & Hummel, 1997). According to the definition by Ferber (1999) in a broad sense, the agent may be a real individual or substance, or a virtual entity. Wooldridge (1997) indicated that, in a multi-agent system, every agent should have the ability of independence, reaction, prediction and interaction. A multi-agent system was used to resolve the system contest in a coordinated and competitive manner (Ishida, 1994; Jennings, Sycara, & Wooldridge, 1998). An agent should have the capability of independence, target-oriented communication and coordination (Fox, Barbuceanu, & Teigen, 2000). Huang and Nof (2000) concluded the characteristics of an agent such as: independence, coordination, target-orientation and responsiveness.

Given the fact of well-developed IT and Internet technologies, many messages must be shared across the sectors, factories and borders. Many difficulties are encountered if message transfer is not conducted in a defined format or standard. Therefore, multi-agent system must be developed in accordance with certain framework and specifications. FIPA (The Foundation for Intelligent Physical) is an international organization of formulating the standards and specifications of agents, with its purpose of enabling the agents to perform their duties everywhere in a certain standard. FIPA was established in 1996, and recognized as 17th standard organization by IEEE in 2005. According to FIPA, the environment is divided into six parts, which are Software, Agent, Agent Management System (AMS), Directory Facilitator (DF), Message Transport Service (MTS) and Agent Platform, as shown in Fig. 2 (Bellifemine, Poggi, & Rimassa, 2001).

JADE (Java Agent Development Framework) was developed by Telecom Italia in accordance with the standards of FIPA. JADE provides a series of function libraries and classes, enabling the program developers to freely and conveniently develop agent system. The agent platform of JADE was developed using JAVA language of Sun Microsystems. JADE has excellent performance thanks to the capabilities of JAVA including: object orientation, multiple sequences, cross-platform and high transportability. JADE agents can act in the platform with JAVA environment, and the agent platform can exist flexibly in various environments based on the capability of JAVA.

The coordination and negotiation process among agents refer to the behavior of integrating multi-agent system. There are available with many negotiation modes, of which the most influential one is Contract Net Protocol. As proposed by Smith (1980), this concept was derived from the out-sourcing projects' bidding procedures in human enterprises, and the issues and conflicts were addressed through multi-agent coordinative negotiation mode as shown in Fig. 3. (1) the manager issues bidding notice to the contractors when a new task is generated; (2) the contractors in idle state will receive the bidding notices from different managers; (3) the contractors make response to the bidding notices, and the managers will receive multiple responsive bidding information; (4) the managers evaluate the bids and select the contractors; and (5) a coordination is established with the selected contractors.

2.3. Using agents in FMS

With the growing scale of FMS and increasingly complicated production processes, many scholars made attempts to improve the performance of FMS by combining it with the agents. To adapt

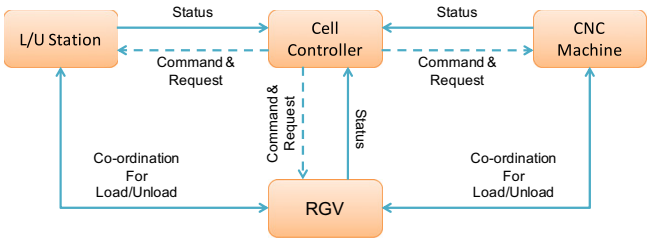

Fig. 1. Relation chart of sub-systems within FMS (Deng & Yang, 1999).

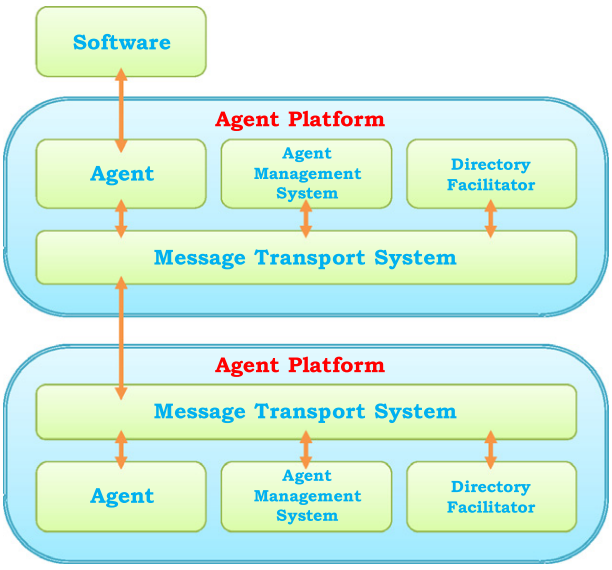

Fig. 2. Agent management reference model (Bellifemine et al., 2001).