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Research on Real-Time Dynamic Scheduling Mechanism of Intelligent Manufacturing System Based on Agent

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Abstract: Based on intelligent agent technology, a new method for dynamic scheduling of chip manufacturing production lines is proposed, which integrates feeding scheduling, workpiece scheduling, and equipment maintenance scheduling. Firstly, a dynamic scheduling model based on intelligent agents is proposed, which includes management agents, feeding agents, workpiece agents, equipment agents, transportation agents, and personnel agents. The feeding intelligent agent is used to achieve feeding control, and workpiece scheduling is achieved through negotiation between the workpiece intelligent agent and the device intelligent agent. Equipment maintenance scheduling is achieved by the device intelligent agent. The mechanism has been explained in detail in terms of scheduling control algorithms and other aspects. This mechanism can achieve real-time control and dynamic scheduling at the workshop level based on the system operation status. Finally, experiments have shown that this method effectively reduces the impact of equipment failures and other disturbance factors on system operation.

Keywords: Real Time, Dynamic Scheduling, Intelligent Manufacturing, Agent

1. INTRODUCTION

The chip manufacturing production line belongs to the third type of production system developed after the job shop and flow shop and can be re integrated into the production system. There are various types of scheduling on chip manufacturing production lines, mainly including feeding control, workpiece scheduling, equipment maintenance scheduling, personnel scheduling, and transportation scheduling. Among them, feeding control, workpiece scheduling, and equipment maintenance scheduling are the focus of research. Quickly and economically establish manufacturing processes based on different product requirements, and dynamically adapt, self-organize, self-learning, liberalize, and maintain the entire manufacturing process.

The research results in the field of distributed artificial intelligence indicate that intelligent manufacturing systems established using agent technology are the most promising development direction. This article first introduces the characteristics of agents and multi-agent systems, and then proposes a method based on dialogue patterns to design communication between agents, which is verified using colored Petri nets. Scheduling strategy in manufacturing system can be divided into static scheduling and dynamic scheduling. Static scheduling refers to generating a scheduling plan for all orders (including assigning designated processing units, processing sequences, and time to enter the production system) before the production system runs. Static scheduling is easy to obtain theoretically optimal or suboptimal scheduling solutions. However, in the actual production process, static scheduling often leads to production stagnation and low production efficiency due to ignoring sudden disturbance factors such as equipment failures and emergency orders.

Unlike static scheduling, dynamic scheduling requires real-time monitoring of various disturbance events that may occur during the operation of the manufacturing system. Once a disturbance event is detected, corresponding processing mechanisms are taken based on the current state of the system to change the scheduling plan, ensuring smooth operation of the system. The dynamic scheduling strategy can effectively handle disturbance events and has become the main scheduling mechanism in current manufacturing systems. The management agent mainly has two functions: managing all agent individuals in the chip manufacturing production line. Each agent in the system needs to register with the management agent, but it only saves relevant information of all agents and does not interfere with the autonomous decision-making of each agent. By managing agents, other agents can easily understand the information they want to know. For example, artifact agents can obtain information about device agents that can complete their own processes through managing agents, to inspire corresponding negotiation processes in a targeted manner.

A multi-agent system consists of a group of many agents distributed logically or physically, connected through a network, sharing resources, and forming an organized group to complete common tasks. It is generally believed that multi-agent systems are particularly suitable for application problems that can be decomposed and partitioned based on space, time, or function. Adopting multi-agent systems in these applications will bring the following advantages: due to the parallelism of processing, the running speed of the system will be accelerated; Since the processing of information is carried out near the information source, the requirements for communication bandwidth are relatively low. The event triggered rolling window dynamic scheduling mechanism utilizes dynamic events in the manufacturing system to partition scheduling intervals.

2. THE PROPOSED METHODOLOGY

2.1 A Dynamic Scheduling Control Architecture Model for Manufacturing Systems

This method divides the dynamic events of the manufacturing system into basic events (foreseeable events during system operation such as process processing completion and workpiece transportation completion) and disturbance events unforeseeable events during system operation such as emergency order arrival and equipment failure. Each equipment agent controls one processing equipment in the chip manufacturing production line. The device agent carries all information about the device, such as type, name, processing capacity, status, geographical location, tools used, queuing for processing workpieces, maintenance methods, and information related to maintenance. The device agent determines whether to undertake the processing task of the workpiece through negotiation with the workpiece agent. In multi-agent systems, coordination and collaboration between agents are key to solving problems. Therefore, agents must exchange information through communication, including goals, intentions, outcomes, and states.

Conversation is the most effective and direct way of exchanging information. Dialogue refers to the behavior of two or more agents conveying a series of messages to achieve a specific purpose. The dynamic scheduling mechanism mentioned above only schedules specific processes of a single production task as the basic unit, and its scheduling process is limited by its own knowledge base. Relying solely on this mechanism cannot guarantee the optimal global scheduling of the system. In addition, scheduling schemes generated by different tasks are likely to generate resource conflicts (such as scheduling schemes for multiple tasks requiring the same processing equipment).

Therefore, in the implementation process of dynamic scheduling mentioned above, corresponding negotiation mechanisms need to be applied to coordinate the agent entities participating in scheduling in the control system. Firstly, the workpiece agent issues a task announcement to the relevant device agent, which mainly includes a description of the pending process of the controlled workpiece, an initial quotation (in this study, the latest start time of the pending process of the controlled workpiece), a deadline for the device agent to respond (i.e., time constraints), and a deadline for reaching an agreement. Within this time constraint, the artifact agent always adheres to its commitments. After receiving the task announcement, the device agent evaluates the task and responds to the workpiece agent with a quotation within the time constraints specified by the workpiece agent. The construction of a dialogue mode starts with the confirmation of all dialogue topics, and then collects and classifies individual communication behaviors to form a pattern. The collection of these patterns can be checked for conflicts and deadlocks using CPN. Through classification, instantiation, inheritance, and aggregation, a set of pattern classes and pattern instances are obtained.

To avoid resource conflicts, the winning AGV agent and device agent sequentially compare the winning task with the prescheduled task in their own task buffer. If the scheduling evaluation values of the new task are better than the tasks cached by both themselves, replace the original cached task with the new task and notify the agent entity of the original cached task publishing unit to reschedule. Otherwise, reject the new task and publish the tasks.

2.2 Real time dynamic scheduling mechanism for manufacturing systems

Petri net is an effective tool to describe the Discrete event dynamic system with distributed, concurrent, and asynchronous characteristics. It uses four elements to model the system model: place, transition, arc, and token. It uses the connection of place, transition, and arc to identify the static structure of the system and describes the dynamic behavior of the system through the excitation of transition and the movement of token. In a multi-agent system, various agent entities coordinate and generate scheduling sequences through a contract network mechanism; When a disturbance event occurs, the multi-agent system immediately initiates a rescheduling to respond to environmental disturbances. In this model, the overall scheduling objective of the system is decomposed into multiple sub objectives and coordinated and calculated by multiple distributed agent entities simultaneously. Therefore, manufacturing systems can generate response rescheduling for disturbance events in a shorter CPU time.

The above considerations are that the devices controlled by the device agent are processed in a single chip or batch manner. When the equipment controlled by the device agent is in a multi batch processing mode, the method for generating a counter quote is the same as the above method when the equipment is idle or in maintenance, and when the equipment is busy but there are no waiting workpieces in front of it. However, when the equipment is in a processing state and there are workpieces waiting to be processed in front, special consideration should be given to prioritizing the processing of workpieces that meet the maximum processing batch of the equipment. This will not be analyzed in detail here. There are many construction methods for composite patterns, such as hierarchical CPN representation and object-oriented analysis and design methods.

Composite patterns can be obtained by integrating some atomic patterns, and there are two main methods of integration: aggregation and connection. The aggregation method can fully utilize the characteristics of colored Petri nets for simulation. For example, aggregating the three atomic modes of REQUEST, REPLY, and ACK into composite modes. For manufacturing control systems in dynamic environments, the basic goal is to achieve smooth and continuous operation of the production system and reduce equipment waiting time. In an ideal situation, the goal of continuous operation of the system can be reflected in two aspects: for the device agent, it is hoped that after the processing task is completed, the workpiece can be immediately transported to AGV to ensure that it can receive processing tasks from other workpieces and achieve continuous processing operations.

The device agent obtains information about device agents with similar functions through management agents. If the devices controlled by similar device agents are not busy, maintenance begins; If the device controlled by a similar device agent is busy, use the management agent to obtain if there are any upcoming workpieces. If not, start maintenance and upkeep. If so, check the processing time and number of machined pieces of the workpiece to determine whether the completion of the workpiece processing will reach the required maintenance value. If so, start maintenance; If not, wait for the workpiece to arrive.

3. CONCLUSION

This article proposes an intelligent manufacturing control system model in a dynamic environment, which can achieve distributed control and real-time dynamic scheduling through multi-agent interaction based on contract networks, based on the actual state of the production workshop. The article establishes a dynamic scheduling control architecture model for manufacturing systems and analyzes the characteristics of communication between agents in the system from the perspective of event triggered rolling window dynamic scheduling mechanism and contract network-based multi-agent coordination control. A communication mechanism based on dialogue mode is proposed, and verified with colored Petri, achieving satisfactory results.

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