A self-organizing manufacturing system adapting to disturbances

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1. Introduction

The productivity and efficiency of the manufacturing systems are reduced by the unexpected disturbances such as the breakdown of machines, the malfunction of robot or transporter. The conventional manufacturing control system is centralization and hierarchism, which is inflexible to adapt to these disturbances. In order to overcome the weakness of the conventional manufacturing system, this paper presents a new manufacturing system model, called Self-Organizing Manufacturing System (SOMS). In this model, the manufacturing system is considered as the community of autonomous entities. Each entity overcomes the disturbance by itself or cooperation with other entities.

2. The model of SOMS

The model of SOMS is described in Figure 1. Cognitive agent technology is used to equip autonomous characteristics and cognitive behaviours such as perception, decision making, learning, inheritance, and cooperation for entities of the manufacturing system [1]. The manufacturing system is considered as a swarm of cognitive agents. This idea is inspired from the natural environment where a collective intelligence is carried out by simple interactions of individuals. A concept found in the colonies of insects, namely swarm intelligence, exhibits this collective intelligence. Swarm intelligence is established from simple entities, which interact locally with each other and with their environment. In ant colonies, the collective intelligence is given by interactions of individual ants with the limited cognitive abilities through chemical substances called pheromones. In order to adapt with the dynamic evolution of environment, a swarm of ants needs the self-organization ability. Self-organization is carried out by re-organizing its structure through a modification of the relationships among entities without external intervention [2].

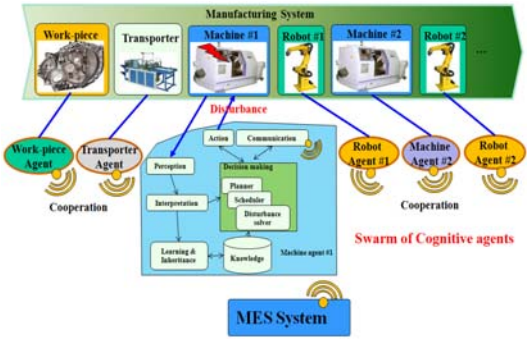

Figure 1. The model of SOMS

In manufacturing systems, self-organization is carried out by locally matching between machine capabilities and product requirements. Each machine has a pheromone value for a specific operation and the machine with the shortest processing time for a specific operation has the highest pheromone [3]. In the SOMS concept, the swarm intelligence technology is applied for an integration of manufacturing scheduling and control in which the manufacturing control architecture is a swarm of agents. Each agent represents a manufacturing resource such as a robot, a machine tool or a work-piece. At the beginning, the Manufacturing Execution System (MES) dispatches the process planning to the corresponding agents based on agent identification (agent ID). Each agent manages the status of the corresponding resource. In case of the occurrence of disturbance such as the tool wear or machine breakdown, the agent activates a non-negotiable plan or negotiable plan depending on the disturbance type to overcome the disturbance. In the non-negotiation, agent overcomes the disturbance

by itself in case the resource still operates otherwise it cooperates with other agents to overcome the disturbance. The agent cooperation is based on the current status of resources and the pheromone values. The machine with the highest pheromone is chosen for carrying out the jobs of the disturbed machine.

3. Mechanisms of SOMS for adapting to disturbances

Figure 2 illustrates the scenario to describe the mechanisms of SOMS. The machining system consists of three machine centers. The process sequence of the machining shop, the initial values of the processing time and the pheromone values of the operations are supposed. An assumption is the task #2 that can be done at any machines. At the beginning, the MES system dispatches the jobs to the corresponding machines based on the machine agent ID. The machining system activates the route #1 in which the machine #1 (M1), machine #2 (M2), and machine #3 (M3) carry out the task #1 (T1), task #2 (T2), and task #3 (T3), respectively. In case of disturbance, the machine agent makes a decision based on the disturbance classification. If the disturbance belongs to non-negotiation type as the tool wear, the machine agent adjusts cutting conditions without affecting to the quality of product. In case the disturbance belongs to the negotiation as the machine breakdown of the machine #2, immediately, the negotiation of machine agents is activated. The machine agent #2 sends a message for help to the remaining machine agents. This message content consists of the machining information and addresses of the receiving machine agents. The machine agents negotiate to find out another route. This negotiation is based on the evaluation of the pheromone values of machine agents, the precedence relationship between the operations, and current status of the machines. The machine has the highest pheromone value that is chosen for carrying out the jobs of machine #2. After negotiating, the machine agent #3 accepts the machining job of the machine #2 based on its own machine information, current status, and work-piece information. The machine agent #3 requests the scheduling information from the MES system, and then cooperates with the transporter and work-piece agent to carry out the accepted job. As the result, the system activates the route #2. This solution is applied to disturbances, which take a short time for recovery. In case the disturbances cause a long recovering time or the negotiation among agents does not have any solution, the request is sent to the MES for rescheduling.

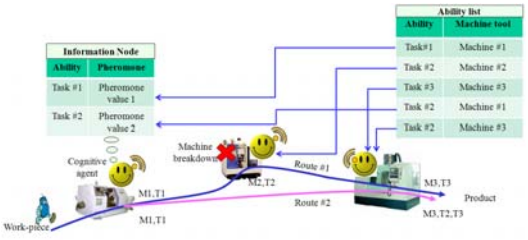

Figure 2. Scenario for adapting to disturbance of the machining system

4. Conclusion

The SOMS with advanced characteristics such as autonomy and cooperation, which are carried out by using the swarm of cognitive agent and ICT progress is a feasible solution to face with the unexpected disturbances of the manufacturing system. The SOMS increases the productivity of the manufacturing system by reduction of downtime of the machine tools caused by the disturbances.

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