A Cognitive Manufacturing System

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1. Introduction

The automated control system is one of the key factors for a cost effective production. The limitation of automated control system is its inability to handle unexpected situations such as collision between a robot and a machine, failure to insert a part into the chuck and so on. When such anomalies occur, the system needs to be reset and restarted [1].

In contrast, human workers with their problem solving abilities, dexterity and cognitive capabilities are still the single way to provide the required flexibility, adaptability and reliability. The reason is that humans have brains, computational mechanisms that are capable of acting competently under uncertainty, reliably handling unpredicted events and situations and quickly adapting to changing tasks, capabilities, and environments. They also cause very high production costs and thus are solely used for small series, prototypes or one-off production.

In order to overcome shortcomings and to combine the advantages of both, automated systems and cognitive capabilities of human, new approaches to manufacturing are required. A new paradigm in production science, that combines research efforts from several different research areas, as neurobiology, robotics, computer science, electrical engineering and mechanical engineering to achieve "the cognitive manufacturing system" [2], is proposed within this paper.

2. Basic idea

The cognitive manufacturing system as a manufacturing environment will consist of different manufacturing resources like production cells, robots and storages, as well as of processes of production and control. The paradigm "cognition" in term of the manufacturing system denotes that machines and processes are equipped with cognitive capabilities and cognitive controls in order to enable them to assess and increase their scope of operation autonomously. A cognitive control consists of three general actions: perceiving information in the environment, reasoning about those perceptions using existing knowledge, and acting to make a reasoned change to the environment. Cognitive capabilities such as perception, reasoning, learning and planning turn technical system into ones that "know what they are doing" [2]. Manufacturing systems with cognitive capabilities will be much easier to interact and cooperate with and they will be more robust, flexible and efficient.

3. Elementary techniques

Cognitive capabilities of human are divided into two functions: communication and intellectual functioning. In communication, human use their senses to know the environment and have reactions to the environment based on self-control. Self-control means human have autonomously decisions to changes of the environment. The decisions are true or failure that depends on their knowledge. The intellectual functioning, with autonomous adaptation, learning, intelligent process planning and collaboration, is tool to form and improve the knowledge.

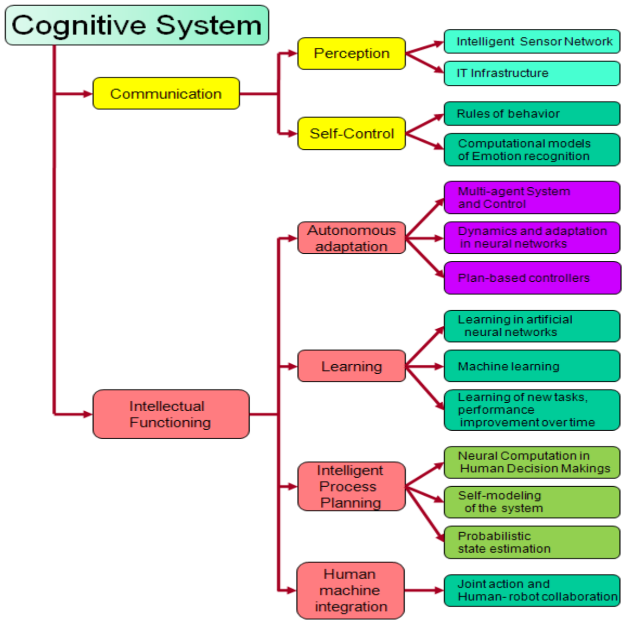

Figure 1. Elementary techniques of a Cognitive system.

Based on analysis about cognitive capabilities of human we propose elementary techniques for development a cognitive system showed at Fig.1. In manufacturing environment, a cognitive system is an information processing system with its data is received by intelligent sensor network and IT infrastructure. The self-control of system is formed based on rules and computational models and decisions for controls of system improve based on intellectual functioning.

4. Whole architecture of a cognitive manufacturing system

The architecture of the integrated system is showed at Fig.2. There are three major components in the architecture: a cognitive system, a shop floor control system and a physical shop floor.

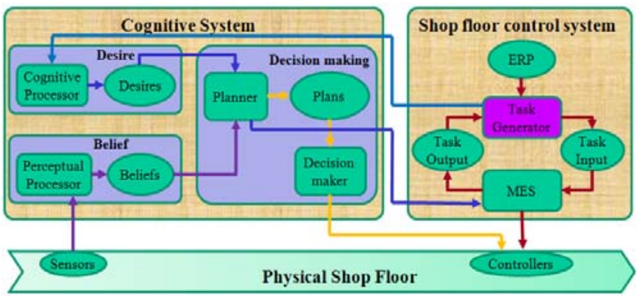

Figure 2. Architecture of a cognitive manufacturing system.

The cognitive system monitors, detects and resolves conflicts to ensure the continued operation of the shop floor. It consists of Belief module, Desire module, and Decision making module. Data from sensors are collected and transformed into a standard format called belief set by the perceptual processor of the Belief module. In the Desire module, the cognitive processor identifies goals and transforms them into desires. The planner of Decision making module generates alternative plans of action based on beliefs and guided by the desires. The generated plans are then stored in the plan set. The decision maker selects an optimal plan and executes it through controllers in the environment.

In the automated shop floor control system, the task generator receives orders from the Enterprise Resource Planning (ERP) system and then generates the sequences of tasks required to produce the orders. The manufacturing execution system (MES) receives tasks from the task generator and controls the equipment controllers in the physical shop floor to execute these tasks. An ‘ok’ message is sent to the task generator by MES when a task is completed and the system continues. In the cognitive manufacturing system, the task generator sends a task command to both the MES and the cognitive system. When the state of the physical shop floor changes, the perceptual processor updates the belief set. The planner compares the beliefs with desires. If the belief set confirms with the goals in desires, an ‘ok’ message is sent to the MES, and the shop floor system continues. If the belief is different from the goal because of occurrence of an error, the planner will further generate new plans that will force the system reach the target state. Then the decision making engine selects one of the optimal plans and executes it in the equipment controllers. The cognitive system then controls the physical shop floor system until the target state is reached.

5. How to apply this concept to practice

The applications of a cognitive system to the manufacturing environment are wide field that depend on applied objects as control, scheduling, disturbance handling, and so on. These manufacturing issues are solved by intelligent way.

To illustrate the applied cognitive system to the manufacturing system Fig.3 shows the architecture of an autonomous system for solving disturbances happened in manufacturing systems. This is an information processing system exploiting aspect intellectual functioning of the cognitive system. In this system, a multi-agent system is developed to keep for manufacturing running when disturbances happen [3], each agent is built based on a cognitive architecture this makes agents have cognitive capabilities and cognitive controls.

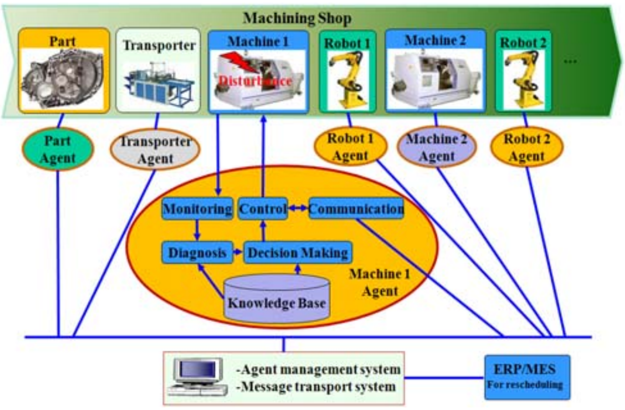

Figure 3. A whole detail concept of an autonomous system architecture

In our application, resources of a machining shop are controlled by agents; they have local knowledge and global knowledge stored in knowledge base. Data for processing disturbances are received by monitoring and analyzed by diagnosis; reaction to disturbances is formed by decision making. This reaction is sent to control for controlling machine. Information of agents is managed by agent management system. The communication between agents through messages is managed by message transport system.

In our example, disturbance happens at machine1; its agent performs decision control based on its knowledge. In case agent is not enough knowledge to solve problem, it implements negotiation with other agents. Its decision making sends request for help to all machine agents. For example, after negotiation the best solution is chosen for machine2 agent, the job at machine1 is performed at machine2 that keeps for manufacturing running. The manufacturing system will use previous plan when machine1 is restored. This solution is applied for short-time disturbances, with long-time disturbances or incase the negotiation between agents doesn’t have solution. The problem is sent to upper layer of the manufacturing system for rescheduling.

6. Conclusion

The cognitive manufacturing system is a trend of modern manufacturing system to cope with uncertainties and disruptions of the manufacturing environment. Manufacturing systems are equipped cognitive capabilities will be more robust, flexible and efficient.

In this paper, we give a brief definition of cognition in term of the manufacturing system and a list of elementary techniques for implementing functions of a cognitive system, based on that we propose a whole architecture of a cognitive manufacturing system. The autonomous system with agents built based on cognitive architecture for solving disturbance happened in manufacturing as illustration for applying the cognitive system to the manufacturing system.

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