Development of an Intelligent Agent based Manufacturing System

Hong-Seok Park[1] and Ngoc-Hien Tran[2]

[1]*School of Mechanical and Automotive Engineering, University of Ulsan, Ulsan 680-749, South Korea*

[2]*University of Transport and Communications, Lang Thuong Ward, Dong Da District, Hanoi, Vietnam*

Keywords: Cognitive Agent, Modern Manufacturing, Self-optimization.

Abstract: The new trend of the manufacturing system development is to apply autonomous behaviours inspired from biology for the manufacturing systems. In which, the resources of the manufacturing system are considered as biological organisms, which are autonomous entities so that the manufacturing system has the advanced characteristics inspired from biology such as self-adaptation, self-diagnosis, and self-optimization. To carry out these characteristics, the paper presents a paradigm about intelligent agent, called the cognitive agent and using cognitive agents for adapting to disturbances such as tool wear, machine breakdown that have happened on the shop floor. Modern manufacturing systems having the distributed control need autonomy and cooperation in solving problems of agents from agent technology, and cognitive capabilities for agents from cognitive technology. Cognitive agents combined from these two technologies are necessary for future manufacturing systems.

1 INTRODUCTION

The human beings can adapt to the environmental changes by the cognitive capabilities such as perception and intellectual functions as shown in Figure 1 in which the learning capability allows the human being to improve the knowledge and skill to adapt to the changes. Currently, human workers with their skills and knowledge adapt to changes of almost activities from design to manufacturing process. The new trend is to apply the decision capability, knowledge, and human being capabilities into the manufacturing system that shows the combination of cognitive science, automation technology, and computer science as shown in

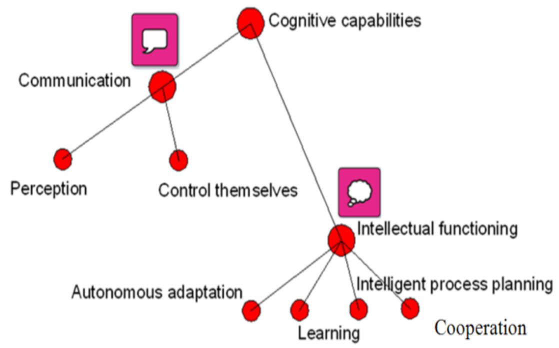

Figure 1: Cognitive capabilities of human beings.

Figure 2. Intelligence in manufacturing systems is shown by the self-learning, self-adaptation, self-diagnosis, and self-optimization capability. These characteristics allow the system to improve the current capability, to diagnose the status. The cognitive models have been studied to apply into manufacturing systems to equip the system with the cognitive capability.

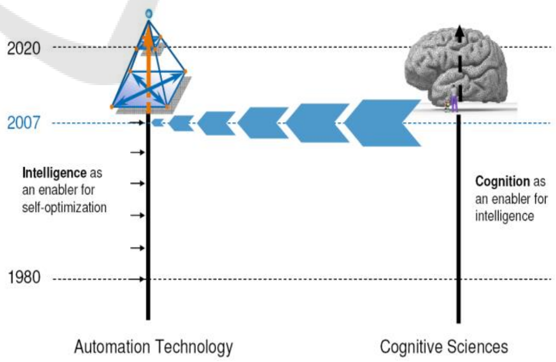

Figure 2: Cognition for realizing intelligence in manufacturing (Tobias, 2009).

The cognitive factory was proposed by Zaeh (2009) in which the advantages of both of automated systems and cognitive capabilities of human were inherited. The cognitive architecture namely Beliefs-Desires-Intentions (BDI) proposed by Zhao and Son

Park H. and Tran N.
Development of an Intelligent Agent based Manufacturing System.
DOI: 10.5220/0006136704450450
In *Proceedings of the 9th International Conference on Agents and Artificial Intelligence (ICAART 2017)*, pages 445-450
ISBN: 978-989-758-220-2

(2008) was applied for the cognitive factory. Machines and their process are equipped with cognitive capabilities to enable the machines for reacting flexibly to the manufacturing changes.

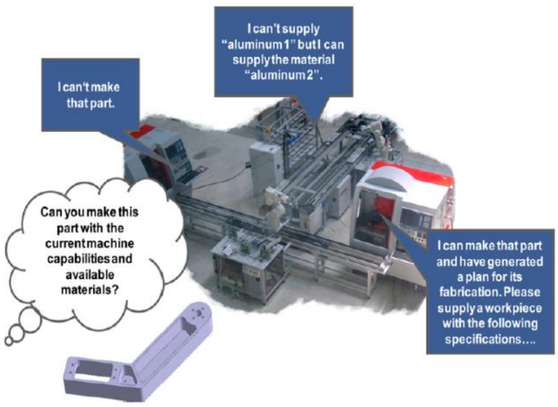

Figure 3: A cognitive machining system (Zaeh, 2009).

The BDI architecture was based on a decision making model of human comprising the knowledge models, perception and control methods, planning mechanism, and a cognitive perception-action loop. The information about status of machines and processes are got from the beliefs module. The states of tasks that the system will carry out are defined as desires. The task's states that the system will work towards are defined as intentions. Figure 3 illustrates a vision of a cognitive machining system. The machines equipped the cognitive abilities can communicate, cooperate, and negotiate to get the optimal manufacturing process.

2 LITERATURE REVIEW

The new trend in manufacturing filed is to apply the bio-inspired technologies to equip the machines and processes with autonomous behaviours as shown in Figure 4. The new concepts in manufacturing have been proposed such as Genetic Manufacturing System (GMS) (Christo, 2007), Biological Manufacturing System (BMS) (Ueda, 2006), Holonic Manufacturing System (HMS) (Leitao, 2002), and Intelligent Manufacturing System with Biological Principles (IMS-BP) (Park, 2010). Autonomy allows the system to recover autonomously without either upper level aids such as the Enterprise Resource Planning (ERP), and the Manufacturing Execution System (MES) or the operator intervention. In these manufacturing system, each entity in the manufacturing system is an autonomous entity so that it can overcome the disturbances by itself or communicate with the others to overcome the disturbances.

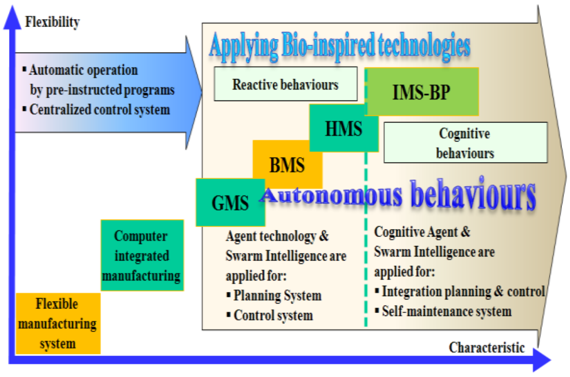

Figure 4: Evolution of manufacturing systems toward the autonomous manufacturing.

On the machine level, the evolution of control techniques toward future machines with intelligent control is summarized in Figure 5. Technical innovations in the hardware and software of machine tools have improved their efficiency, allowing the application of CNC machine tools in machining automation that is both highly accurate and productive (Nakamoto, 2004, Shirase, 2009).

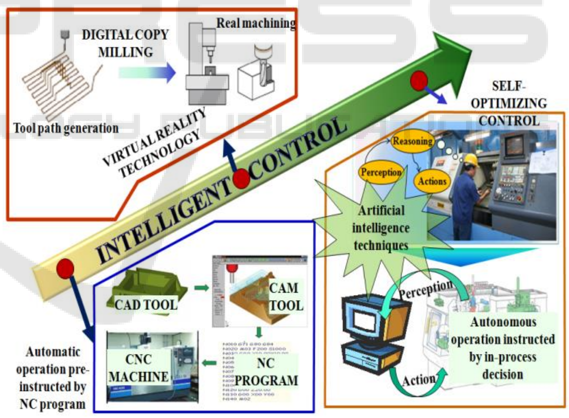

Figure 5: Trend of intelligent control techniques.

3 CORE TECHNOLOGIES

Figure 6 shows the classification of agents including biological, robotic, and software agents. In this research, the agents for controlling the manufacturing system are software agents which are computer programs. The agents have the advanced characteristics as autonomy, social ability, reactivity, and pro-activeness (Monostori, 2006, Leitao, 2009). Autonomy is the ability of agent for achieving its

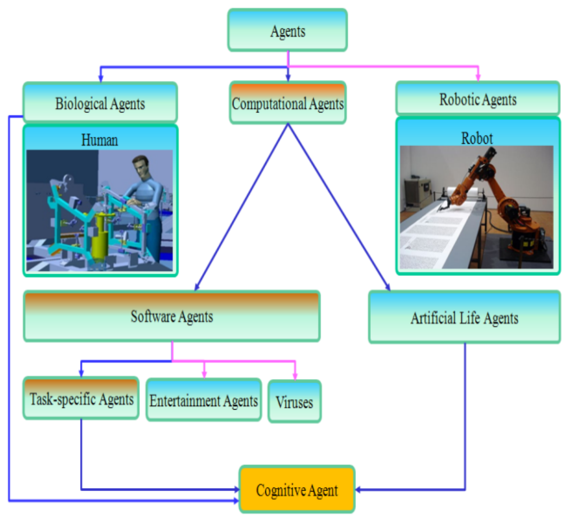

Figure 6: Agent classification.

goals without any support from the other agents. Agent cooperation for getting the global goal of the system is called the agent's social ability. The reactivity is the ability of agents to respond to the manufacturing changes basing on the relation between perception and action. The agent's pro-activeness is the ability to express the goal-directed behaviours.

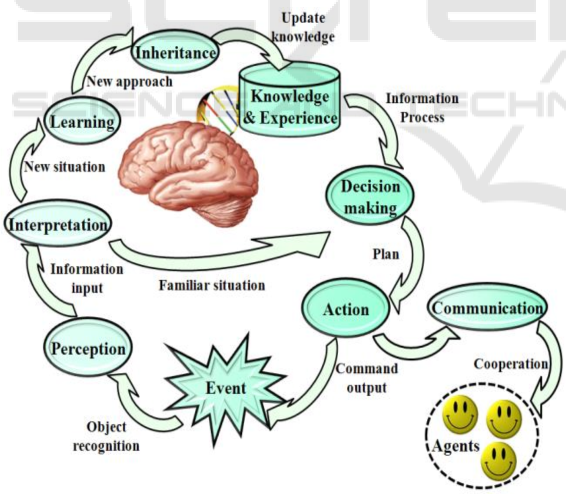

Figure 7: Architecture of cognitive agent.

The cognitive agent is a computer program which uses the BDI architecture inspired from the human decision-making model to arm an agent with artificial cognitive capabilities as shown in Figure 7. The agent performs cognitive activities such as perception, reasoning, and execution (Zhao, 2008) that emulate the human cognitive behaviours. The cognitive agent inherits all characteristics from the traditional agent, including the autonomy, social ability, reactivity and pro-activeness. The different feature in comparison with the conventional agent, which is shown by the improvement of the pro-activeness characteristic, is the intelligence of the cognitive agent. Intelligence is the ability of the agent to use its knowledge and reasoning mechanisms for making a suitable decision with respect to the environmental changes.

4 COGNITIVE AGENTS BASED MANUFACTURING SYSTEM

With the traditional manufacturing system, the information systems such as manufacturing execution system (MES) keep the main role for operating the manufacturing system. In the intelligent agent based manufacturing system, at normal status, the shop floor is controlled by the MES. In case the disturbance happen such as tool wear, machine breakdown and so on, the agent system controls the operation by agent cooperation. Figure 8 shows the information model of the intelligent agent based machining system.

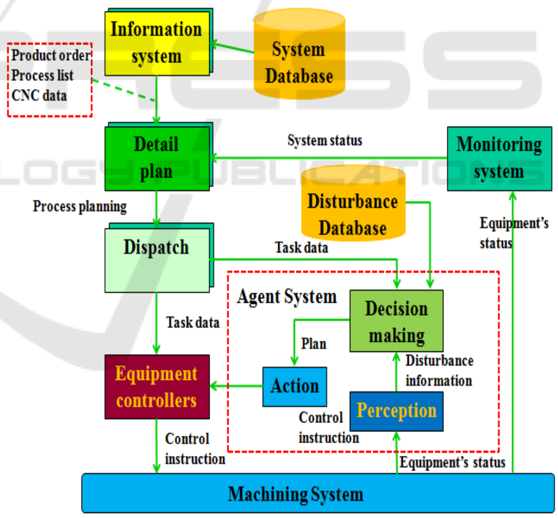

Figure 8: Architecture of cognitive agent based manufacturing system.

The .NET platform and C# were used for programming intelligent agents. Figure 9 show he system architecture with information flow of the intelligent based machining system. For carrying out the system, three kernel issues such as the interaction protocol, agent behaviours, and database (DB) must be focused on. The extensible markup language (XML) messages are used for interacting between agent with MES as well as with other agents. Communication among agents with the programmable logic controllers (PLC) is established using the process control protocol (OPC) for linking and embedding objects. The physical devices on the machining system such as sensors, alarm device, and the controlled machine connect to PLCs. SQL Server^{TM}2005 was used for programming database (DB).

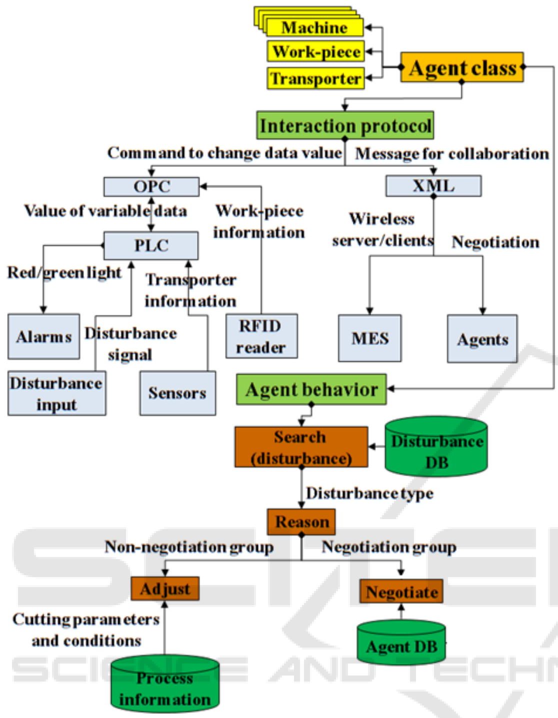

Figure 9: System architecture of the autonomous machining shop.

The functionality of the developed agent system was tested successfully on the test-bed. Model of the test-bed is shown in Figure 10. The working method of the test-bed is explained as follows:

- RFID Reader sends the work-piece ID to PLC (denoted by 1).
- Work-piece agent gets the work-piece ID from PLC and sends to the machine agent (denoted by 2).
- The machine agent requires the task from MES (denoted by 3).
- The machine agent sends the task to PLC (denoted by 4).
- PLC turns on the green light (denoted by 5).
- After finishing the task, PLC turns off the light (denoted by 6).
- PLC sends the signal to the transporter agent to transfer the work-piece to the next machine (denoted by 7).
- Inputted disturbance (denoted by 8).
- PLC sends the signal to the machine agent (denoted by 9).
- Agent overcomes the disturbance by itself or cooperation with the other machine agents.

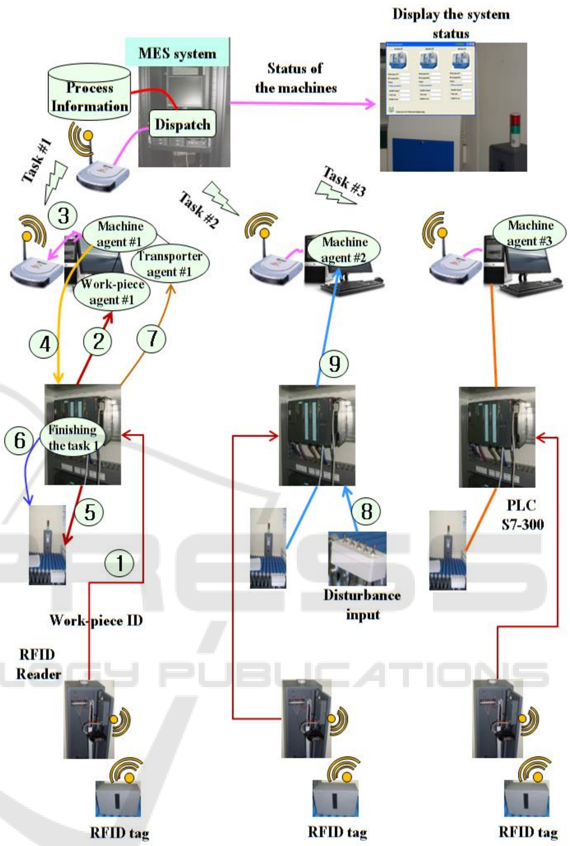

Figure 10: System architecture of the machining shop.

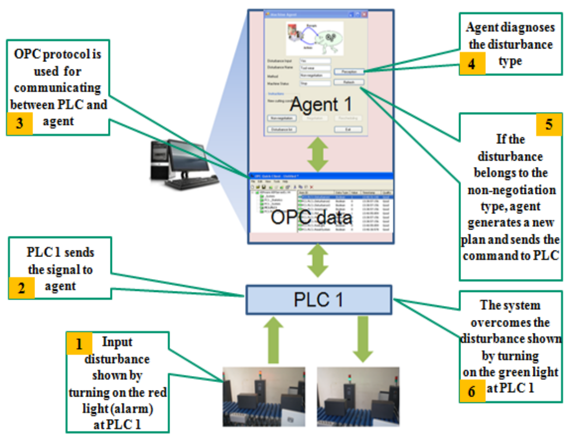

Figure 11: Reaction of the agent in the case of tool wear.

The reaction of the developed system in the case of tool wear is shown in Figure 11. Steps of this case are explained as follows:

- Input disturbance shown by turning on the red light (alarm) at PLC 1.
- PLC 1 sends the signal to agent.
- OPC protocol is used for communicating between PLC and agent.
- Agent diagnoses the disturbance type.
- If the disturbance belongs to the non-negotiation type, agent generates a new plan and sends the command to PLC.
- The system overcomes the disturbance shown by turning on the green light at PLC 1.

The reaction of the developed system in the case of machine breakdown is shown in Figure 12. Steps of this case are explained as follows:

- Input disturbance shown by turning on the red light (alarm) at PLC 1.
- PLC 1 sends the signal to agent.
- Collecting data.
- Agent diagnoses the disturbance belonging to the negotiation type.
- Agents establish the wireless network to server
- Agent negotiation as shown in Figure 13.
- An appropriate agent is selected for carrying out the job of the failure machine.
- The system overcomes the disturbance shown by turning on the green light at PLC 2.

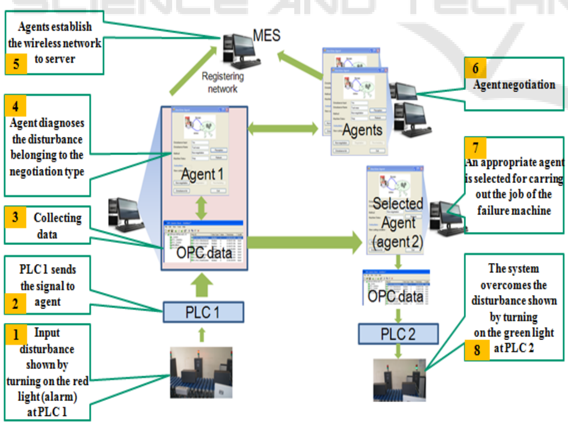

Figure 12: Reaction of the agents in the case of machine breakdown.

5 CONCLUSIONS

Cognitive agents enable the manufacturing system to adapt flexibility to changes and disturbances without upper level aids or a total planning modification. In the cognitive agent based manufacturing, the cognitive capabilities such as perception, reasoning, and cooperation are equipped for resources on the shop floor. In order to prove the efficiency of the proposed cognitive agent concept, the test-bed was implemented and focused on the self-adjustment mechanism in the case of the disturbances. The experimental results show that the mechanism of the proposed system enables the system to adapt to the disturbances successfully.

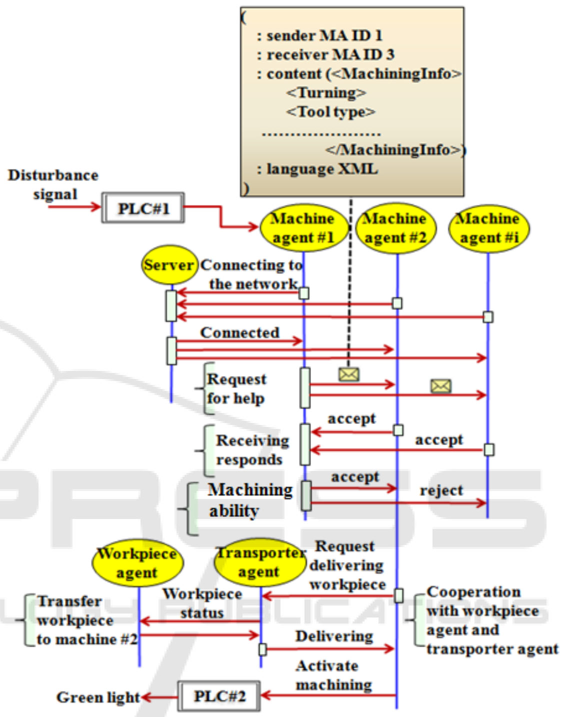

Figure 13: Agent negotiation process.

REFERENCES

Christo, C., Cardeira, C., 2007. Trends in intelligent manufacturing systems, *Proceedings of the IEEE International Symposium on Industrial Electronics*, pp.3209-3214.

Leitao, P., 2009. Agent-based distributed manufacturing control: A state-of-the-art survey, *Engineering Applications of Artificial Intelligence*, 22(7): 979-991.

Leitao, P., Restivo, F., 2002. Agent-based holonic production control, *Proceedings of the 13th International Workshop on Database and Expert Systems Applications*, 589-596.

Monostori, L., Váncza, J., Kumara, S.R.T., 2006. Agent – based system for manufacturing, *CIRP Annals - Manufacturing Technology*, 55(2):697-720.

Nakamoto, K., Shirase, K., Wakamatsu, H., Tsumaya, A., Arai, E., 2004. Development of an innovative autonomous machine tool for dynamic product planning, *Science and Technology of Advanced Materials*, 5:283-291.

Park, H.S, Tran, N.H., 2010. An intelligent manufacturing system with biological principles, *International Journal of CAD/CAM*, 10(1):39-50.

Shirase, K., Fujii, S., 2009. Machine tool automation, *Handbook of Automation*, Springer, pp. 837-857.

Tobias, K., Werner, H., Christian, B., 2009. SOAR-based sequence control for a flexible assembly cell, *Proceeding ETFA'09 Proceedings of the 14th IEEE international conference on Emerging technologies & factory automation*, 2009.

Ueda, K., Kito, T., Fujii, N., 2006. Modeling biological manufacturing system with bounded-rational agents, *Annals of the CIRP*, 55(1):469-472.

Zaeh, M.F., Beetz, M., Shea, K., et al., 2009. The cognitive factory. In: EIMaraghy, H.A (ed) *Changeable and reconfigurable manufacturing systems*, Springer, pp.355-371.

Zhao, X., Son, Y., 2008. BDI-based human decision-making model in automated manufacturing systems, *International Journal of Model and Simulation*, 28(3):347-356.