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Development and evaluation of intelligent machine tools based on knowledge evolution in M2M environment†

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Abstract

In the near future, the foreseen improvement in machine tools will be in the form of a knowledge evolution-based intelligent device. The goal of this study is to develop intelligent machine tools having knowledge-evolution capability in Machine to Machine (M2M) wired and wireless environment. The knowledge evolution-based intelligent machine tools are expected to be capable of gathering knowledge autonomously, producing knowledge, understanding knowledge, applying reasoning to knowledge, making new decisions, dialoguing with other machines, etc. The concept of the knowledge-evolution intelligent machine originated from the process of machine control operation by the sense, dialogue and decision of a human expert. The structure of knowledge evolution in M2M and the scheme for a dialogue agent among agent-based modules such as a sensory agent, a dialogue agent and an expert system (decision support agent) are presented in this paper, and work-offset compensation from thermal change and recommendation of cutting condition are performed on-line for knowledge-evolution verification.

Keywords: Machine-tools; Knowledge evolution; Agent; Cooperation; M2M

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1. Introduction

Machine-tools may be the subject of cooperation in future production systems. It is foreseen that machine tools operating in the M2M environment will be able to autonomically evolve in their knowledge, maintaining the cooperation between various internal and external factors [1-3]. In this study, the design of a dialogue agent module will be presented on the basis of standard platform analysis and ping agent analysis. The purpose of designing a dialogue module agent is for its use in the development of the knowledge-evolutionary intelligent machine tool. An apposite processing system able to process an enormous amount of knowledge in place of human experts is needed in developing the knowledge-evolutionary intelligent machine tools [4-6]. It will also be necessary to develop an agent for intermachine cooperation [5-7]. The knowledge-evolutionary intelligent machine tools will operate by three mechanisms. First, it will have a sensory function similar to that of humans. Second, it will have a communicational function, it will acquire knowledge based on indirect experiences from other experts using the human-dominated linguistic ability. Lastly, it will have a reasoning function. The sensory function, communicational function, and reasoning function will be performed by the sensory module, dialogue module, and expert system respectively, as shown in Fig. 1.

In this study, the agential concept of the dialogue module, which is necessary for intermachine cooperation, will be presented in the three modules. Furthermore, the FIPA-OS, which is a framework based on agent, a related simple agent, and a dialogue agent

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advanced from it will be presented. The dialogue agent, which functions as a dialogue module, communicates with other machinery, using the communication agent. It will acquire knowledge based on indirect experiences by communicating with other machinery that has the knowledge relevant to a particular task assigned. The designed dialogue agent will be applied in coming up with the recommended cutting conditions and thermal error compensation in tapping machines. Through this study, supported by the study on sensory agent and decision support agent. the implementation of knowledge-evolutionary machine tools is expected to become easier.

2. Intelligent machine tools in M2M

Machine tools have always been regarded as objects of integration, but if intelligence technologies for knowledge evolution are developed, it is expected that they may be the subject of cooperation. Fig. 2 shows the outline of a Machine to Machine (M2M) environment that could be expected to minimize the roles of human experts and to substitute for mechanical experts. Machine-dependent knowledge and machine-independent knowledge are examples of types of information exchangeable in an M2M environment. The information may make evolution of knowledge possible with the exchange of information in real time with computer-aided manufacturers, tool makers and marketers, material producers and marketers, remote service distributors, even e-machines. Fig. 3 shows the outline of intelligent machine tools of which knowledge can be evolved within the M2M manufacturing system.

As previously stated, it has three agents, namely, the sensory function, the communication function, and the reasoning function.

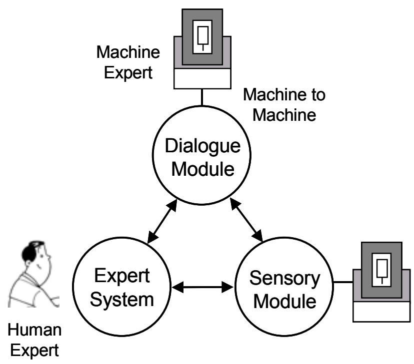


Fig. 1. The three object modules.

3. Agent platform and Inter-agent communication

The dialogue agent manages windows and acquires knowledge from indirect experiences by communicating with other machinery. The dialogue agent or the communication agent was constructed based on FIPA-OS (Open Source) or JADE (Java Agent Development Framework), the software agent platform that implemented FIPA agent standard, as illustrated in Fig. 4. Italy's JADET, Japan's Comtec, USA's AAP and UK's Nortel Network were included in the agent standard-oriented platform. Upon evaluation, FIPA was found to be the most suitable to multi-agent standard (Poslad et al., 2000). FIPA-OS has several basic agents and factors, such as DF (Directory Facilitator), agent management system, agent communication system, IPMT (Internal Platform Message Transport), agent shell, etc., that are able to terminate and generate agents as well as provide ACL (Agent Communication Language) message. DF service makes it possible to retrieve specific agents. The agent management system lists agents or cancels the registration; the agent communication channel (ACC)

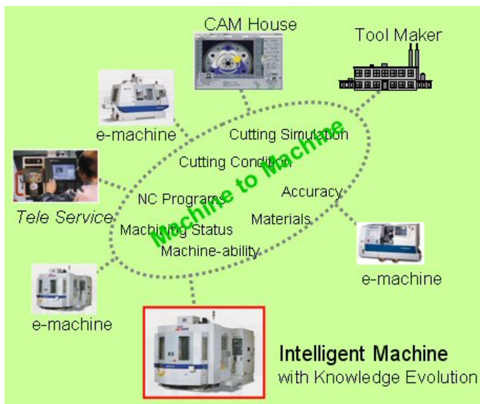


Fig. 2. M2M manufacturing system.

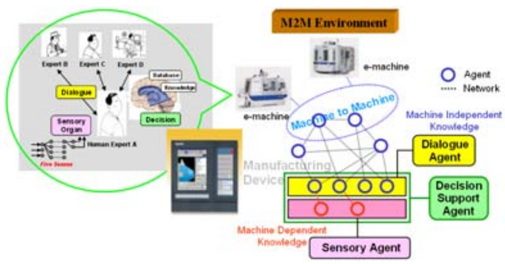


Fig. 3. Knowledge-evolutionary intelligent machine tools in M2M environment.

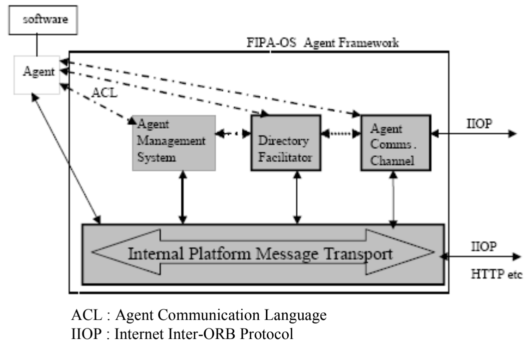


Fig. 4. FIPA-based agent standard platform.

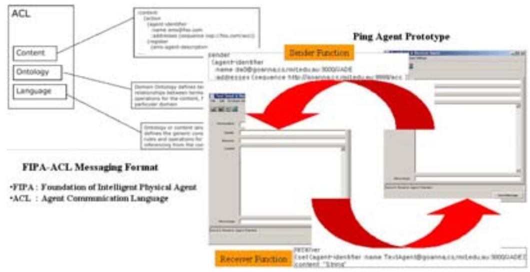


Fig. 5. FIPA-ACL-based ping agent prototype.

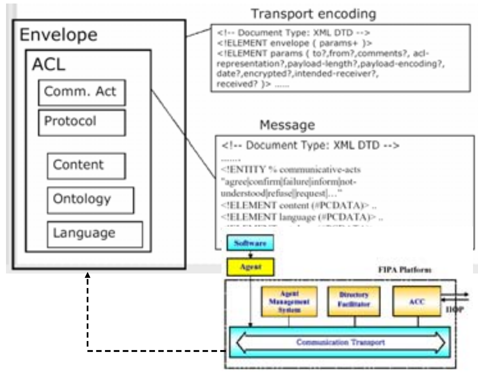


Fig. 6. FIPA-based agent communication using ACL message.

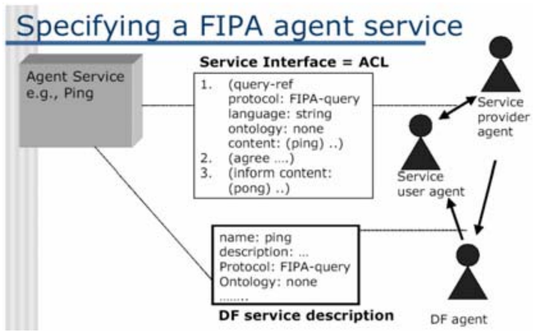


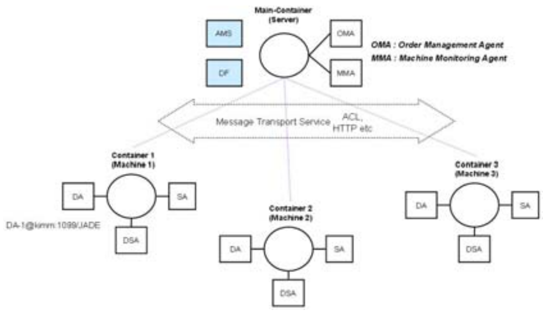
Fig. 7. FIPA-based service between agents.

supports the inter-agent communication and the agent shell provides the basic framework so that new agents may be generated. The agent shell is based on Java class, and new agents are produced by inheriting traits from the basic class. Furthermore, the agent shell manages the ACL messages and contains the class pertaining to the protocol standard. IMPT provides message routing service for the agents produced from a specific agent shell. FIPA-OS, the software agent platform that implemented the FIPA agent standard, was analyzed to implement dialogue agent, as well as to present inter-agent communication and the scheme of dialogue agent.

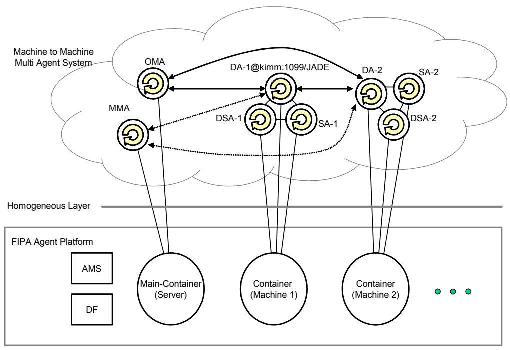
This chapter also deals with the program and its application. It is necessary to implement a demo program for transmitting and receiving string during agent operation. It is of importance that JVM, JDK and FIPA-OS should be operated after their versions are made compatible with each other. The agent loader should be analyzed and GUI window should be generated so that the ping agent may be implemented and messages may be exchanged. The analyzed ping agent should also be registered on the agent loader. The GUI, form and dialogue file in the agent loader were analyzed and the dialogue usable in text-transmitting and receiving program was constructed. Message transmitting and receiving was appositely corrected by analyzing the ping agent. Fig. 5 shows the agent modeled as such. With regard to the communication between FIPA-based agents, ACL is the most important component. Fig. 6 shows the agent communication using ACL and FIPA-based messaging. Fig. 7 shows the outline of the inter-FIPA agent service. The agent using ping in DF is identified and retrieved, and service interface is implemented by the query through the ACL envelope.

The following concretely shows the M2M interface and the relativity between agent and component for the basic studies on internet/agent application:

Fig. 8 shows a pattern of the interface between FIPA-based agents shown in the M2M environment. The outline of agents necessary for the knowledge-evolutionary intelligent machine tools in M2M environment is shown in (a), while (b) shows the machinery, which is broadly classified into the container, as well as the pattern of intermachine or inter-agent interfaces. Such designs and illustrations make it possible to study the multi-agent application.



(a) FIPA-platform-based agents in M2M



(b) Interconnected interface in the M2M FIPA platform

Fig. 8. Communication and interface of agents in M2M.

4. Dialogue agent

Fig. 9 shows the scheme of the dialogue agent. The dialogue agent acquires knowledge from indirect experiences through communication with other machinery and files this information, for use in case a task is given. The internal sensory agent and decision agent are linked with the interface part of the dialogue agent through the communication agent. The communication agent can communicate with M2M, that is, the external agents of other machinery. The data passes through the interface part of dialogue agent, which judges the usefulness of the data received from the interpreter. In addition, it determines the action suitable for the task, concurrently passing through the dialogue engine with the social knowledge that manages the agent for reasoning cooperation. The result is re-sent to the communication agent through the dialogue engine and the interface part.

As shown in Fig.10, the ultimate goal of the dialogue agent is to function as the dialogue window to improve its knowledge by accumulating such knowledge from other machinery, in instances where external knowledge is needed to perform a task.

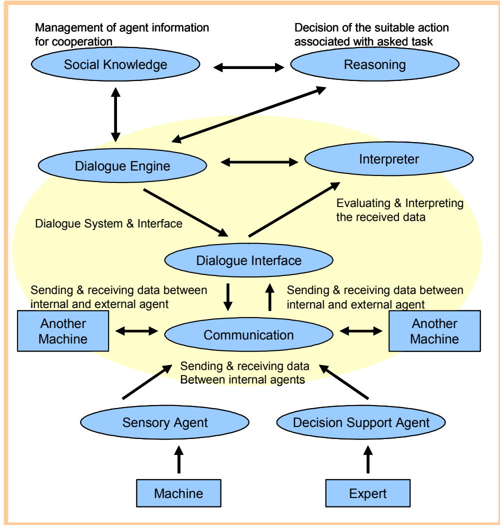


Fig. 9. Scheme of the dialogue agent.

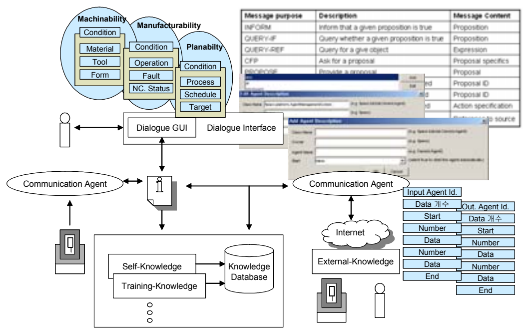


Fig. 10. Structure diagram of the dialogue agent.

It makes possible not only the development of intelligent machinery by sharing information but also the communication of useful information and knowledge to the "on-the-job" and "out-of-the-way" humans and machines. Moreover, it will make possible the development of the knowledge-evolutionary intelligent machines by stages.

5. Application

To derive actual data from the sensor, thermal change and deformation-measuring experiment was applied to the tapping machine. The tapping machine is a tool used to make female screws used for automobile parts, electronic parts, mechanical parts, etc. It is an important core machine used in almost all the industries. Fig. 11 shows the outline of the thermal change and deformation-measuring experiment. The thermal signals of the respective axes (X, Y, and Z)

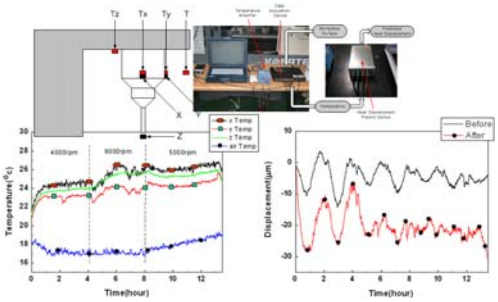


Fig. 11. Data acquisition for thermal error compensation.

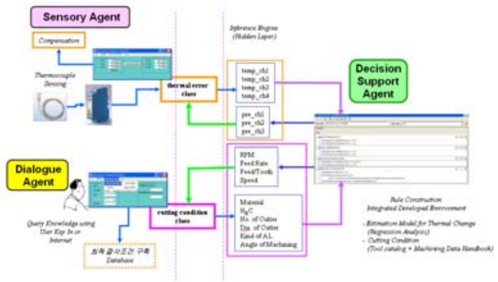


Fig. 12. Data interface by dialogue agent.

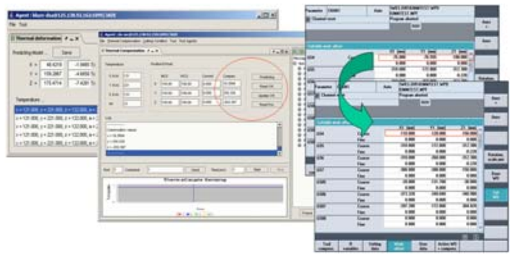


Fig. 13. Thermal error compensation through dialogue agent.

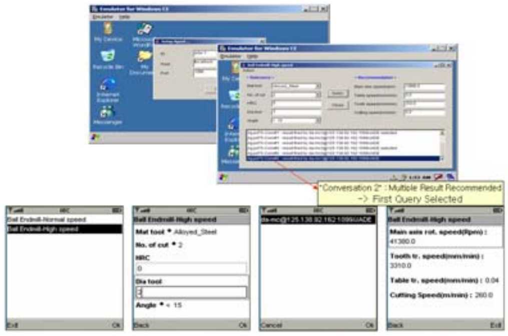


Fig. 14. Cutting condition recommendation through dialogue.

are amplified by the amplifier (ADAMS 3000) then digitalized and stored by an A/D converter. The deformation of the respective axes are fixed by using an eddy current-type cap sensor, and measured at the position where thermal change was measured then stored after amplification and conversion. Atmospheric temperature was between about 15 and 18 degrees centigrade, showing a variation of 3 degrees centigrade.

As shown in Fig. 12, the dialogue agent generally manages the sensory agent, the decision support agent and interface, to process an enormous amount of knowledge including the knowledge concerning the machine-dependent thermal deformation and the machine-independent cutting condition. For instance, in the case of the ball-end mill, usually used in mold processing, an interrogatory knowledge is regularly applied when a cutting condition is given in the dialogue agent. In particular, the cutting conditions such as RPM, feed rate, feed/tooth, main speed, etc., which are necessary for processing work, are given when inputting information about the work piece, such as materials, hardness, necessary tools, etc.; the same is applicable for thermal deformation. Fig. 13 shows a sample of thermal compensation and Fig. 14 shows a sample of cutting condition. If a machine in which the knowledge or information concerning the cutting condition is not inputted, it receives related knowledge from other machines in which such knowledge was already inputted. This system makes evolution possible. This system may be applicable to machine-independent knowledge such as cutting conditions.

However, the system may be unsuitable for machine-dependent knowledge received from other machines, such as thermal compensation, because the temperature around the machines influences the application even with the same machine having the same position

This problem may be gradually solved upon consideration of such conditions.

6. Evaluation

Fig. 15 shows the manufacturing error by thermal change for 13 hours 30 minutes of manufacturing time. The average manufacturing error is approximately 16.5um. Fig. 16 shows the characteristic evaluation of manufacturing accuracy. The error by thermal change is improved by more than 64 percent by manual compensation. However, the error by manual compensation is higher than real-time automatic compensation method by approximately 1.9 percent, and the manufacturing time by manual compensation is also higher by 9.1 percent than conven

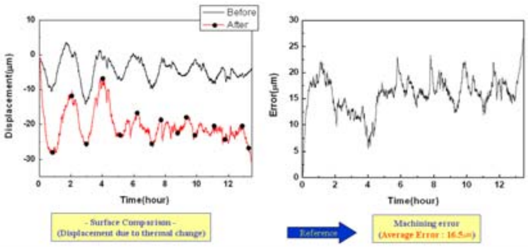


Fig. 15. Machining error by thermal change.

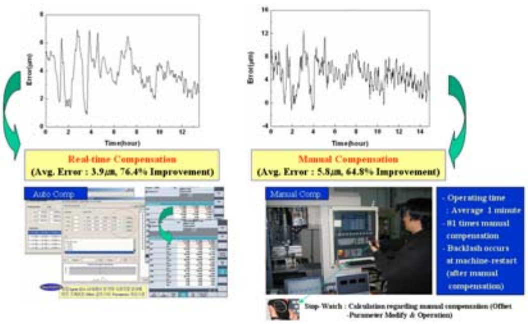


Fig. 16. Characteristic evaluation of manufacturing accuracy.

tional manufacturing. This is because more manufacturing time is consumed in manual compensation such as during offset-parameter modification, and machine operation such as stopping and restarting. Results show that the error by thermal change is improved by more than 76.4 percent by real-time automatic compensation.

7. Conclusion

This study was performed to design a dialogue agent among the sensory agent, the dialogue agent, and the decision support agent, necessary in the development of the knowledge-evolutionary intelligent machine tool. The FIPA platform, a standard operative environment, and the ping agent were analyzed and implemented, and studies on the effectivity of the dialogue agent were performed. In this study, the function of dialogue agent in the M2M environment, suitable to the development of knowledge-evolutionary intelligent machines, was presented in consideration of intermachine cooperation. The concept of agent-based dialogue module was presented between the pattern of knowledge-evolutionary intelligent machines and the objective models of knowledge. The dialogue agent was designed by centering on FIPA-based message interface after the basic analysis of the ping agent in M2M environment, and an actual application was performed. In the actual machine application, work-offset compensation from thermal change and recommendation of cutting condition are performed on-line for knowledge-evolution verification.

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