Knowledge-Evolutionary Intelligent Machine-Tools
— Part 1 : Design of Dialogue Agent based on Standard Platform

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In FMS (Flexible Manufacturing System) and CIM (Computer Integrated Manufacturing), machine-tools have been the target of integration in the last three decades. The conventional concept of integration is being changed into the autonomous manufacturing device based on the knowledge evolution by applying advanced information technology in which an open architecture controller, high-speed network and internet technology are included. In the advanced environment, the machine-tools is not the target of integration anymore, but has been the key subject of cooperation. In the near future, machine-tools will be more improved in the form of a knowledge-evolutionary intelligent device. The final goal of this study is to develop an intelligent machine having knowledge-evolution capability and a management system based on internet operability. The knowledge-evolutionary intelligent machine-tools is expected to gather knowledge autonomically, by producing knowledge, understanding knowledge, reasoning knowledge, making a new decision, dialoguing with other machines, etc. The concept of the knowledge-evolutionary intelligent machine is originated from the machine control being operated by human experts' sense, dialogue and decision. The structure of knowledge evolution in M2M (Machine to Machine) 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, with intent to develop the knowledge-evolutionary machine-tools. The dialogue agent functions as an interface for inter-machine cooperation. To design the dialogue agent module in an M2M environment, FIPA (Foundation of Intelligent Physical Agent) standard platform and the ping agent based on FIPA are analyzed in this study. In addition, the dialogue agent is designed and applied to recommend cutting conditions and thermal error compensation in a tapping machine. The knowledge-evolutionary machine-tools are expected easily implemented on the basis of this study and shows a good assistance to sensory and decision support agents.

Key Words : Machine-Tools, Knowledge Evolution, Dialogue Agent, Cooperation, M2M, FIPA

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1. Introduction

The machine-tools may be the subject of cooperation in future production systems. Specifically, it is expected that the machine-tools may con-

struct M2M (Machine To Machine) environment that autonomically evolves its knowledge, maintaining the cooperation between various internal and external factors (Kim et al., 1999; 2000; 2004; 2003; Kim, 2002). In this study, the design of dialogue agent module was presented on the basis of standard platform analysis and ping agent analysis, on purpose to design a dialogue module agent for developing the knowledge-evolutionary intelligent machine tool. It is because an enormous amount of knowledge and an apposite processing system, which can substitute human experts, are so needed that the knowledge-evolutionary intelligent machine-tools can be developed (Kim, 2002; Park, 2002; Whang et al., 2001; Hu et al., 2003; Choi, 1997). Hereupon, it is necessary to develop an agent for inter-machine cooperation (Kim et al., 2004; Kim and Koh, 2004; Poslad et al., 2000; Cantamessa, 1997). More than all, the concept of standard framework named 'FIPA-Open Source' was presented prior to the design of such a dialogue module. Likewise, a basic agent using named 'ping agent' was analyzed and the scheme of dialogue agent, which is equivalent to the dialogue module necessary to develop the knowledge-evolutionary intelligent machine-tools in M2M environment, was presented. The knowledge-evolutionary intelligent machine-tools has three mechanisms. First, it has the sensory function similar to that of humans. Secondly, it has communicational function. Namely, it acquires the knowledge based on indirect experiences from other experts, using the human-dominated linguistic ability. Lastly, it has reasoning function. The sensory function, communicational function and reasoning function can be performed by sensory module, dialogue module and expert system as shown in Fig. 1.

In this study, the agential concept of the dialogue module, which is necessary for inter-machine cooperation, was presented among the three modules. In line with this object, FIPA-OS, a framework based on agent, and a related simple agent were presented and also a dialogue agent advanced from it was presented. The dialogue agent that functions as a dialogue module communicates with other machinery, using communication
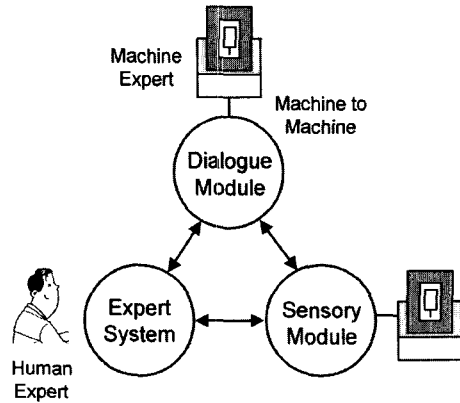

Fig. 1 Three Object Modules

agent. Namely, it acquires the knowledge based on indirect experiences by communicating with other machinery having the relevant knowledge in case a task is assigned. The designed dialogue agent is applied for the recommendation of cutting conditions and thermal error compensation in tapping machine. Through this study, the knowledge-evolutionary machine-tools is expected to be hereafter more easily implemented with the assistance of the study on sensory agent and decision support agent

2. Intelligent Machine-Tools in M2M

Machine-tools have been regarded as integration the object of integration, but it is expected that those may be the subject of cooperation if intelligence technologies for knowledge evolution are developed. Figure 2 shows the outline of M2M (Machine to Machine) environment that is expected to minimize the roles of human experts and to substitute mechanical experts. As regards the information exchangeable through M2M environment, machine-dependent knowledge and machine-independent knowledge are representative. The information may make it possible to evolve knowledge, exchanging information in real time with computer-aided manufacturers, tool makers and marketers, material producers and marketers, and remote service distributors not to mention e-machine. Figure 3 shows the outline of intelligent machine-tools of which knowledge
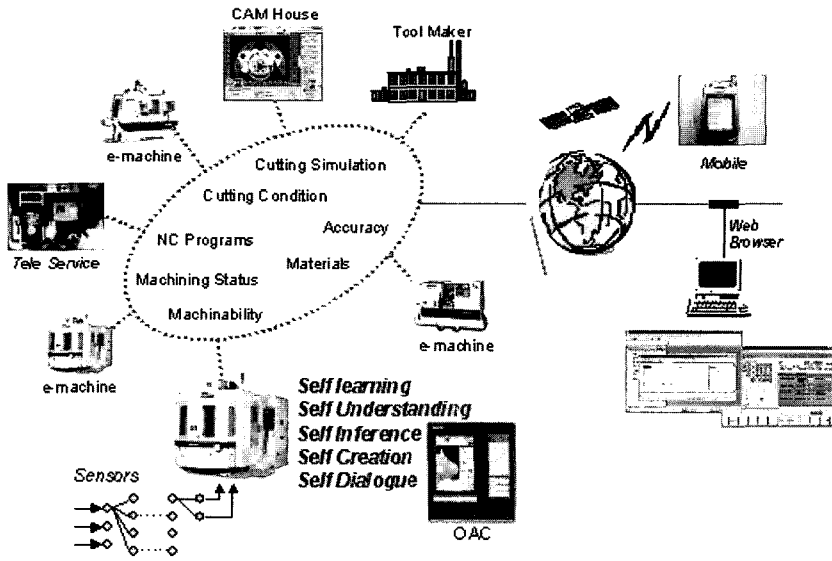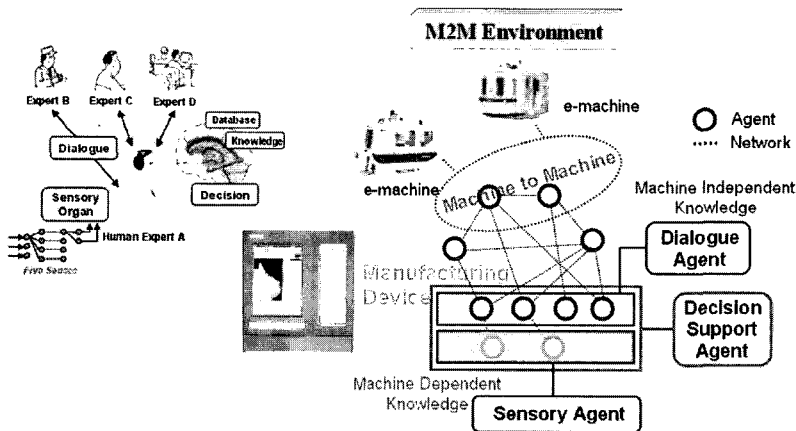
Fig. 2 M2M Manufacturing system

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

can be evolved in the M2M manufacturing system. As previously stated, it has three agents such as sensory function, communicational function and reasoning function.

3. FIPA–Based Agent Standard Platform

The dialogue agent acquires the knowledge based on indirect experiences by communicating with other machinery and manages windows. The dialogue agent or the communication agent are constructed on the basis of FIPA-OS (Open Source)

or JADE (Java Agent Development Framework), the software agent platform that implemented FIPA agent standard presented in Fig. 4. Italy's JADET, Japan's Comtec, USA's AAP and UK's Notel Network are included in the agent standard-oriented platform. In particular, it is evaluated that FIPA is 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., in order to terminate and generate agents and to provide ACL (Agent Com-

munication 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) supports inter-agent communication and the agent shell provides the basic framework so that agents may be generated. The agent shell is based on Java class, and new agents are produced by inheriting from the basic class. Likewise, the agent shell manages ACL message and contains the class pertaining to protocol standard. IMPT provides message routing service for the agents pro-

duced on the basis of a specific agent shell. FIPA-OS, the software agent platform that implemented FIPA agent standard, was analyzed to implement dialogue agent as well as to present inter-agent communication and the scheme of dialogue agent.

4. Inter-Agent Communication Analysis

This chapter deals with the program, which is necessary to implement a demo program for transmitting and receiving string in agent operation, and its application. Above all, JVM, JDK and FIPA-OS should be operated after matching their versions with each other. The agent loader should be analyzed and GUI Window should be generated so that ping agent shown in Fig. 5 may be implemented and messages may be mutually exchanged, and the analyzed ping agent should be registered on the agent loader. The GUI, form and dialog file in the agent loader were analyzed and the dialog usable in text-transmitting and receiving program was constructed. Message transmitting and receiving was appositely corrected by analyzing ping agent. The Fig. 6 shows the agent
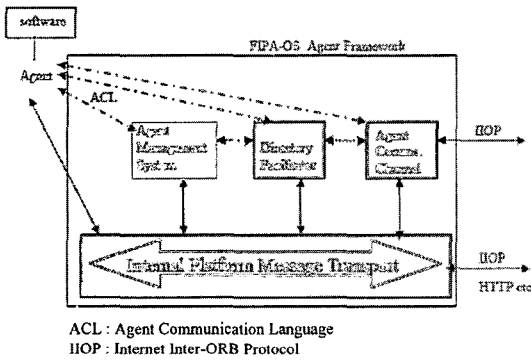

ACL : Agent Communication Language
IIOP : Internet Inter-ORB Protocol

Fig. 4 FIPA based agent standard platform

Service Name	Ping Agent
Service Address	PingAgent@lurcher5.cs.rmit.edu.au:9999/JACK
Service Description	Replies with an "alive" (no quotes in the version sent) confirmation message (with a FIPA performative INFORM) when it receives a FIPAQUERY-REF message with the single word "ping" in the body.
Content Language	Plain Text
Protocol	FIPA QUERY
Interface	The PingAgent accepts a message like the following

(QUERY-REF
  :sender
  (agent-identifier
    :name da0@goanna.cs.rmit.edu.au:3000/JADE
    :addresses (sequence http://goanna.cs.rmit.edu.au:9999/acc))
  :receiver
  (set (agent-identifier :name PingAgent@goanna.cs.rmit.edu.au:3000/JADE))
  :content Ping
)

The PingAgent generates a reply as follow:

(INFORM
  :sender
  (agent-identifier
    :name PingAgent@goanna.cs.rmit.edu.au:3000/JADE
    :addresses (sequence http://goanna.cs.rmit.edu.au:9999/acc))
  :receiver
  (set (agent-identifier :name da0@goanna.cs.rmit.edu.au:3000/JADE
    :addresses (sequence http://goanna.cs.rmit.edu.au:9999/acc)))
  :content Alive
) |
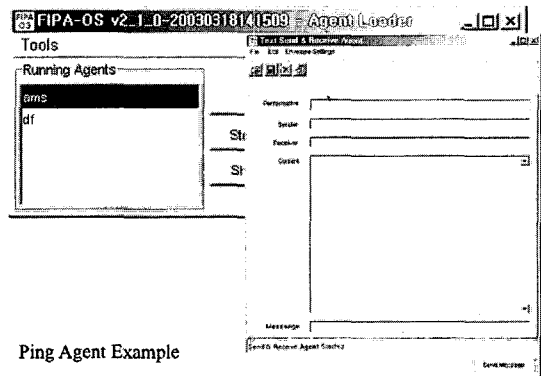
Ping Agent Example

The Ping Agent will try to ping all the other ping agents that it knows about every 5 minutes, and will respond to any pings it receives. It does this with tasks:
IdleTask: Is started first. Gets all other agents from DF.
After 5mins it starts pinging (PingALLTask).
It also responds to any pings it receives (PingResponseTask).
PingAllTask: Sends a ping to all agents (PingTask).
PingTask: Sends a ping.
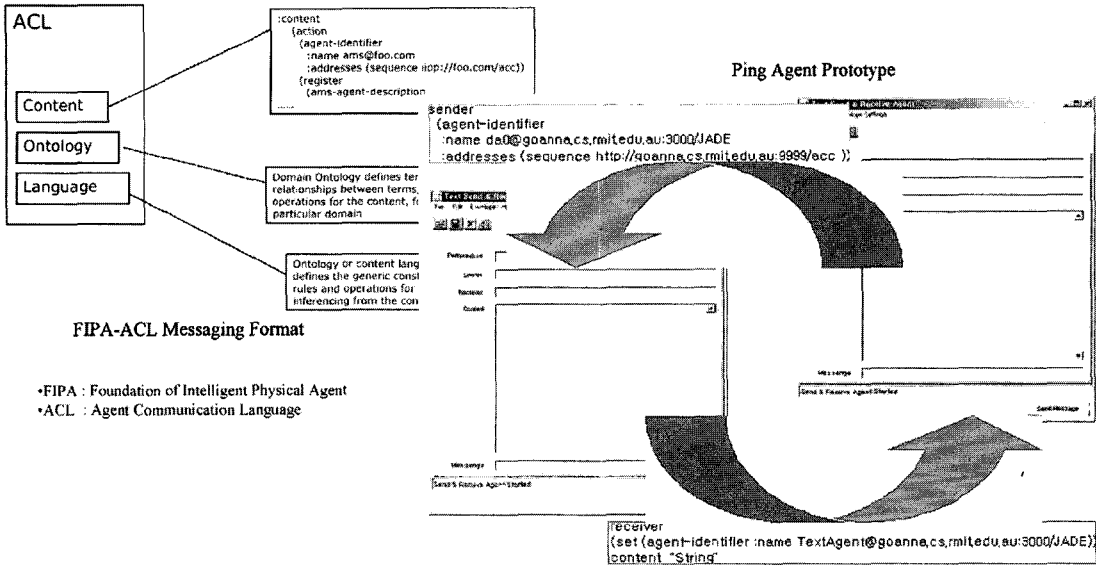PingResponseTask: Replies to pings.

Fig. 5 Analysis of ping agent

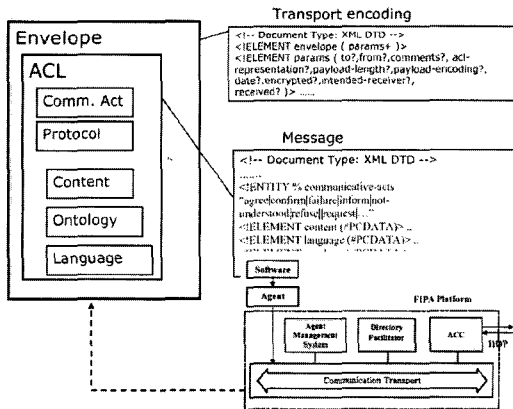**Fig. 6** FIPA-ACL based ping agent prototype

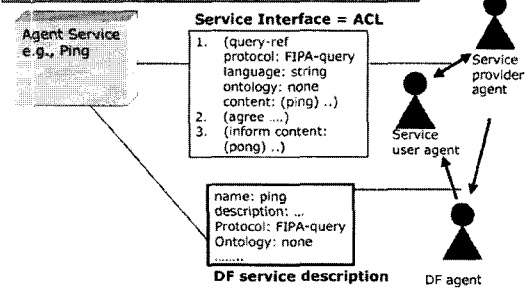**Fig. 7** FIPA-based agent communication using ACL message

Fig. 8 FIPA-based service between agents

DF : Directory Facilitator
AMS : Agent Communication System
ACL : Agent Communication Channel
ACC : Agent Communication Language
MTS : Message Transport Service
RMI : Remote Method Invocation
CORBA : Common ORB Architecture
ORB : Object Request Broker

Fig. 9 Structure for message transmission between platforms

modeled so. As regards the communication between FIPA-based agents, ACL is most important. The Fig. 7 shows the agent communication using ACL and FIPA-based messaging, and the Fig. 8 shows the outline of inter-FIPA agent service. Namely, the agent using ping in DF is retrieved and service interface is implemented by the query through ACL envelope.

The followings concretely show M2M interface and the relativity between agent and component for the basic studies on internet/agent application. The Fig. 9 shows the RMI (Remote Method
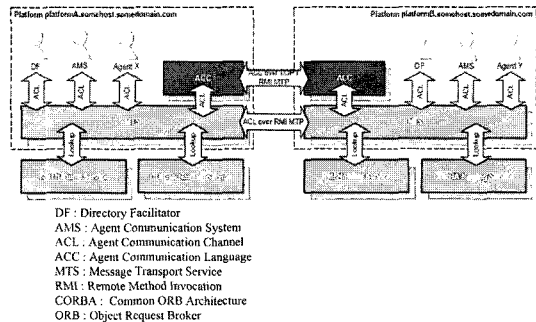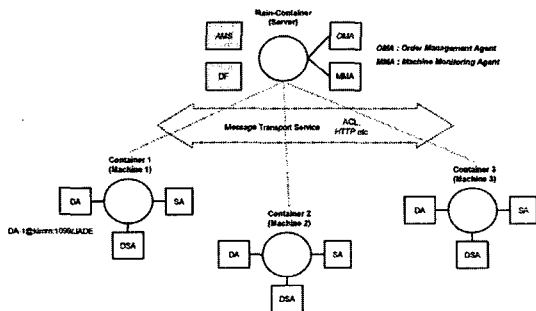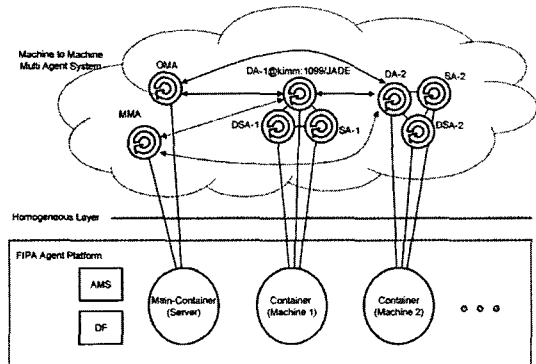
Invocation) and the message-transmitting service that perform between the platform-A and the platform-B. The Fig. 10 shows a pattern of the

(a) FIPA-platform based agents in M2M

(b) Interconnected interface in M2M FIPA platform

Fig. 10 *Communication and interface of agents in M2M*

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

5. Dialogue Agent

The Fig. 11 shows the scheme of dialogue agent. It acquires the knowledge based on indirect experiences and files such information through communication with other machinery, in case a task is given. The internal sensory agent and decision agent are linked with the interface part of dialogue agent through the communication agent. The communication agent can communicate with
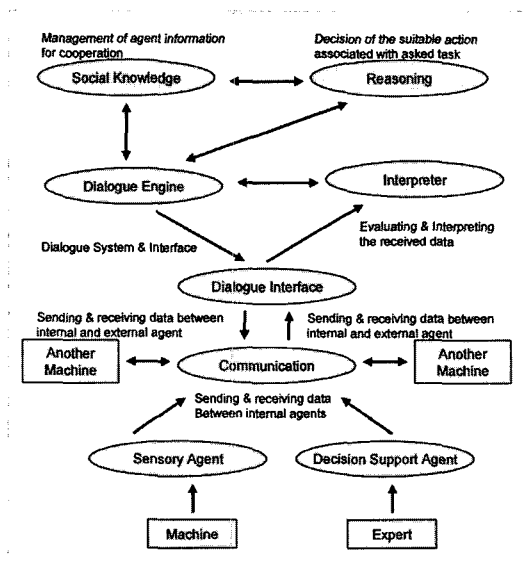

Fig. 11 Scheme of dialogue agent

M2M, that is, the external agents of other machinery. The data, passed through the interface part of dialogue agent, judges the usefulness of data received from interpreter. In addition, it determines the act suitable to the task called concurrently with the social knowledge that manages the agent for reasoning cooperation passed through the dialogue engine. The result is resent to the communication agent by passing through the dialogue engine and the interface part.

As shown in the Fig. 12, the ultimate goal of dialogue agent is to function as the dialogue window with intent to improve knowledge on the basis of the knowledge accumulated from outside machinery, in case outside knowledge is needed to perform a task. It makes it possible to not only develop intelligent machinery by sharing information but also communicate useful information and knowledge to the on-the-job and out-of-the-way humans and machines. Moreover, it will make it possible to develop the knowledge-evolutionary intelligent machines by stages.

6. Application

To derive actual data from the sensor, thermal change and deformation-measuring experiment was applied to the tapping machine. The tapping

machine is to make female screws that are used for automobile parts, electronic parts, mechanical parts, etc. In a word, it is a core machine necessary for almost all the industries. The Fig. 13
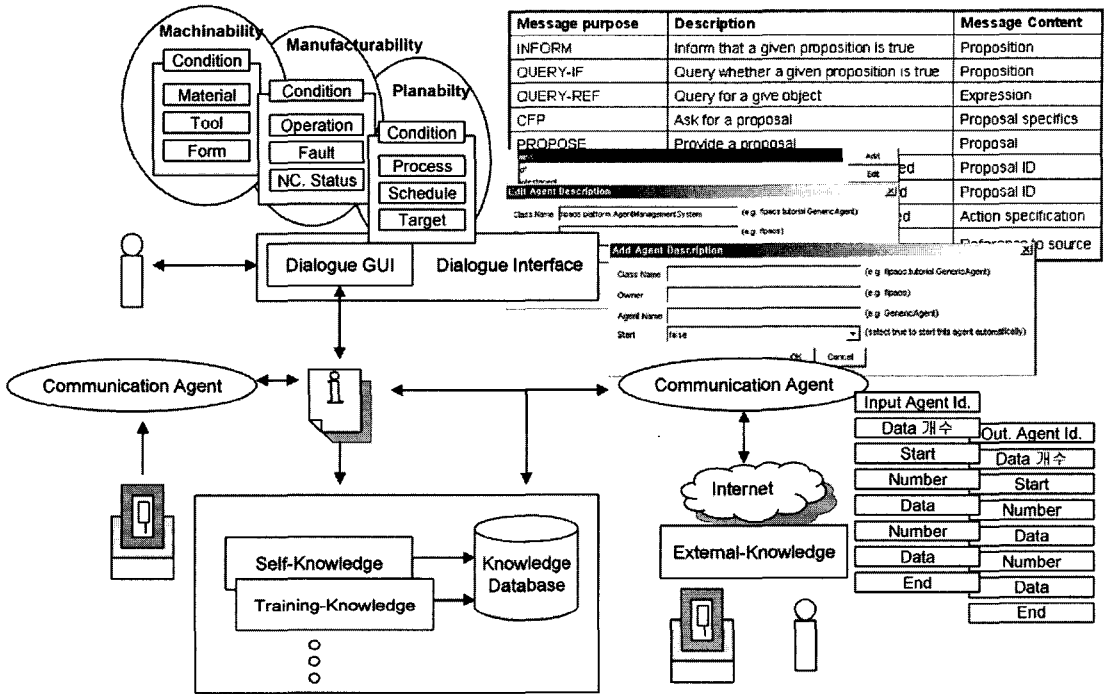

Message purpose	Description	Message Content
INFORM	Inform that a given proposition is true	Proposition
QUERY-IF	Query whether a given proposition is true	Proposition
QUERY-REF	Query for a give object	Expression
CFP	Ask for a proposal	Proposal specifics
PROPOSE	Provide a proposal	Proposal
		Proposal ID
		Proposal ID
		Action specification

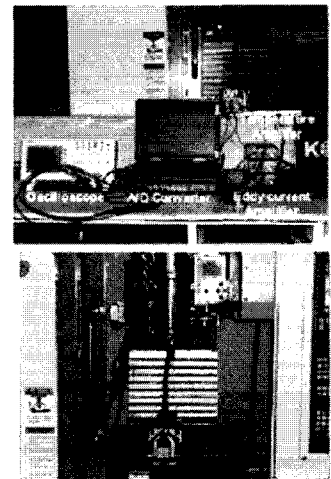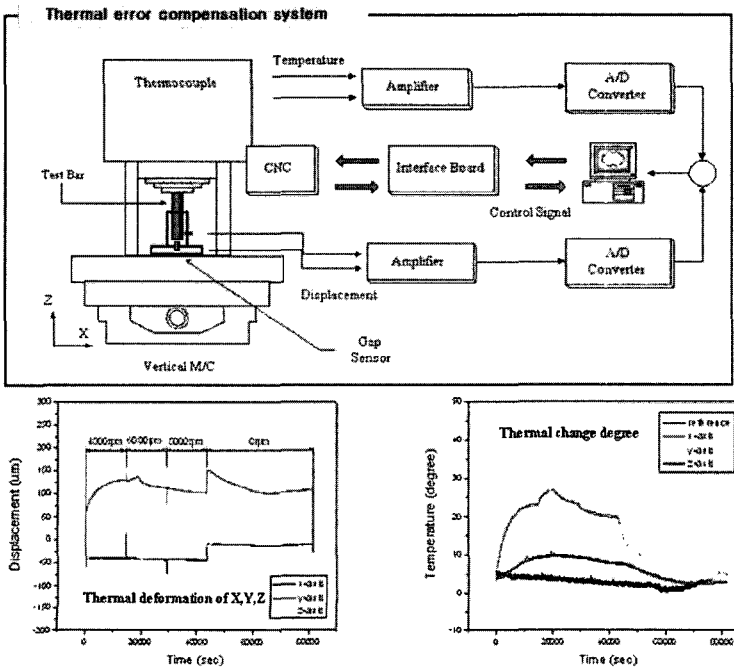**Fig. 12** Structural diagram of dialogue agent

Fig. 13 Data acquisition for thermal error compensation

shows the outline of thermal change and defor-mation-measuring experiment. The thermal sig-nal of respective axes (X, Y and Z) is amplified

by the amplifier (ADAMS 3000) and is digi-talized and stored by an A/D converter. The de-formation of respective axes is fixed by using an
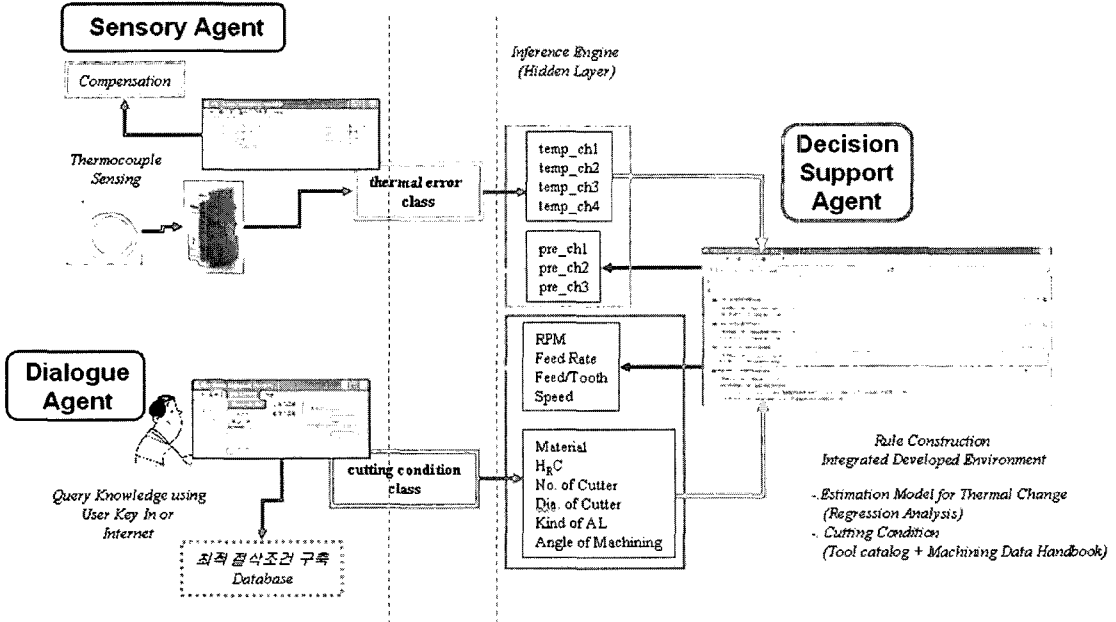

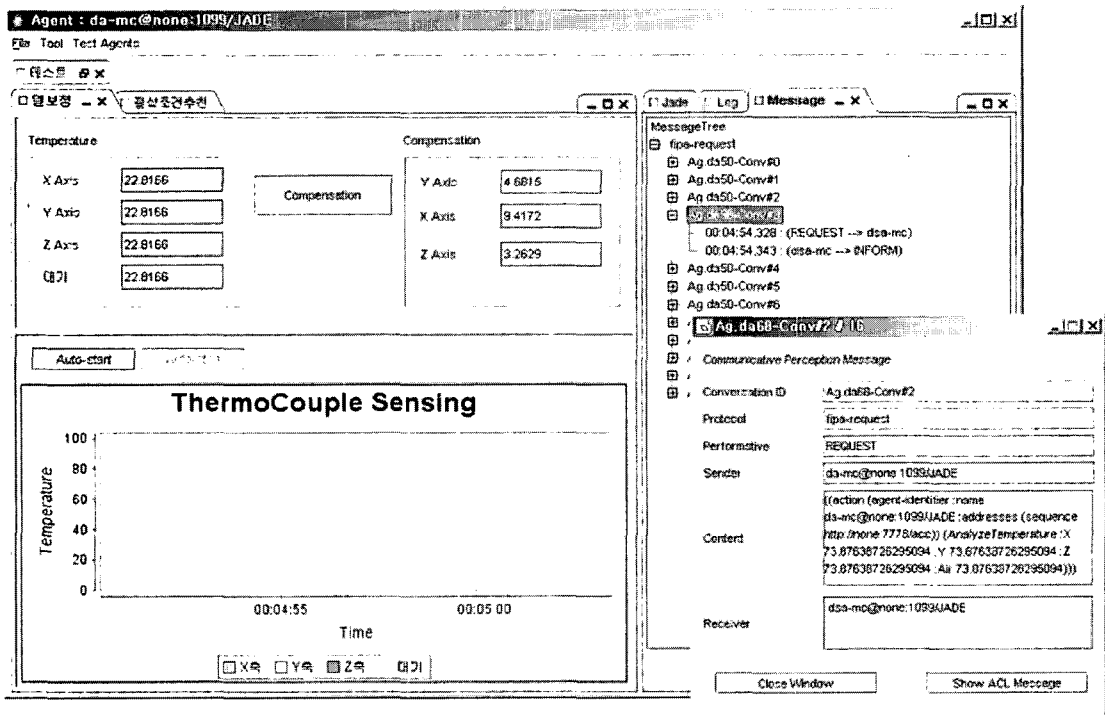Fig. 14   Data interface by dialogue agent

Fig. 15   Thermal error compensation through dialogue agent

eddy current-type cap sensor, and is measured at the position where thermal change was measured and is stored after amplification and conversion. Atmospheric temperature was between about 3.2 and 5.2 degrees centigrade, that is, shows the variation of 3 degrees centigrade. As shown in Fig. 14, 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, an interrogatory knowledge is regularly applied to the case of the ball-end mill, which is used most in mold processing, in case a cutting condition is given in the dialogue agent. To be exact, the cutting condition necessary for processing work such as RPM, feed rate, feed/tooth, main speed, etc. is given in case of inputting the information of workpiece such as materials, hardness, necessary tools, etc., same as thermal deformation. The Fig. 15 shows a sample of thermal compensation and the Fig. 16 shows a sample of cutting condition. In case of a machine in which

the knowledge concerning cutting condition is not inputted, it receives the related knowledge from other machines in which such was already inputted. This system makes evolution possible. Actually, the machine-dependent knowledge like cutting condition could be applied as it is. On the other hand, the machine-independent knowledge received from other machines, like thermal compensation, was unsuitable, because the temperature around machine had influence on the application despite the same machine and the same position. This problem should be gradually solved in consideration of such conditions.

7. Conclusions

This study was performed with intent to design the dialogue agent among the sensory agent, the dialogue agent and the decision support agent necessary to develop the knowledge-evolutionary intelligent machine tool. FIPA platform, a standard operative environment, and the ping agent were analyzed and implemented as well as the studies on effective dialogue agent were performed.
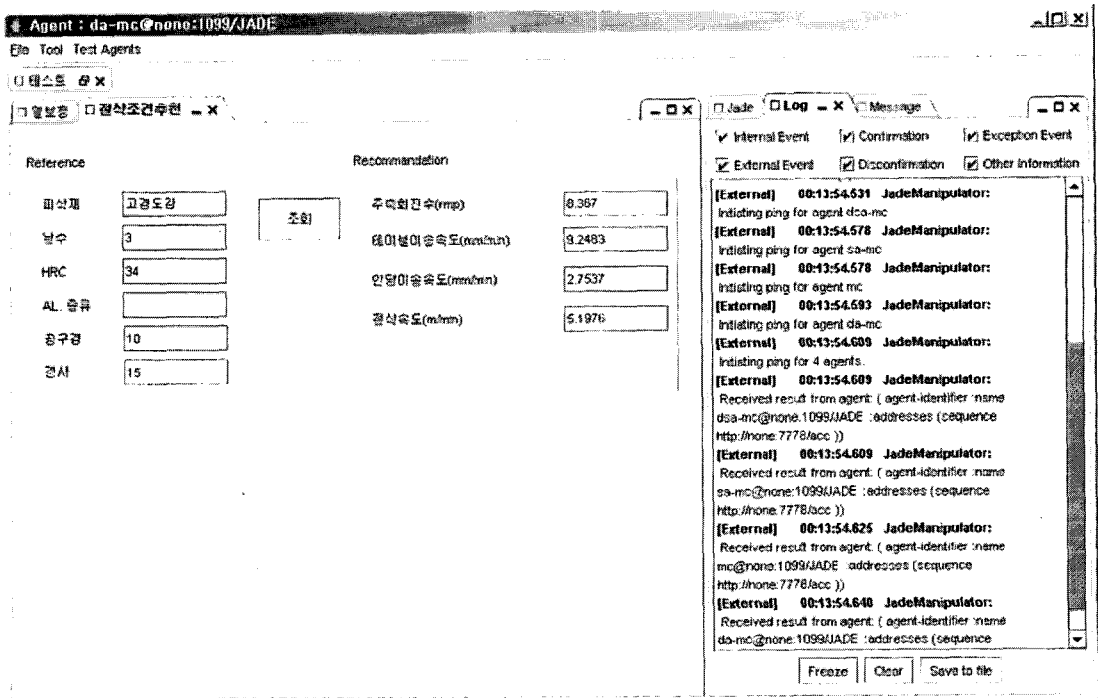

Fig. 16 Cutting condition recommendation through dialogue agent

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 inter-machine cooperation. Namely, the concept of agent-based dialogue module was presented between the pattern of knowledge-evolutionary intelligent machines and the objective models of knowledge. In particular, the dialogue agent was designed by centering on FIPA-based message interface after the basic analysis of ping agent in M2M environment, and actual application was performed. The study is scheduled to be carried out in consideration of the expandability of dialogue agent, simultaneously with the sensory agent and the decision support agent.

Acknowledgements

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