Research advances of distributed artificial intelligence and multi-agent system

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ABSTRACT

With the rapid development of computer technology and wide application of artificial intelligence, engineering practice puts forward a higher requirement to the computer's ability of dealing with and solving complex problems. At first, this paper mainly introduces the relative theories of distributed artificial intelligence, the concept of multi-agent and the structure of multi-agent system. Then, it analyzes the problems which a single artificial intelligence meets in practice and discusses the basic principle of distributed artificial intelligence to solve the problem. Also, it illustrates the application of multi-agent in practice and summarizes the current development situation, main research direction and unsolved problems of multi-agent system. Finally, combining these aspects above, it discusses the future development trend of distributed artificial intelligence.

KEYWORDS

INTRODUCTION

The concept of Agent was first proposed in 1986, generally translated as agent. Since it was proposed, the agent theory has become a universal concept in many industries. At the same time, it became a field which developed faster than others in artificial intelligence. This made people begin to pay attention to the artificial intelligence technology which had reached a low point at that time. The breakthrough characteristic of agent theory is that it considers the communication and interaction of human intelligence and break through the limitation of traditional artificial intelligence theory which is established in single agent. With the development of computer technology and Internet technology, the computational problems of industry complex system puts forward the higher requirement for the computer processing power, and the centralized processing of a single computer cannot meet the requirement. So, parallel computing or distributed system is applied in the calculation system of industry, and the combination of distributed theory and artificial intelligence forms the idea of distributed artificial intelligence. Due to the characteristics of agent fit the characteristics of distribution, so agent occupies a leading position in the field of artificial intelligence, and pushes forward the advancement of distributed artificial intelligence technology [1, 2]. Single agent has many limitations on allocation of resources, spatial and temporal distribution and function. But, relatively, distributed artificial intelligence can overcome these shortcomings and it has many advantages, such as openness, paralleling and fault tolerance. The distributed artificial intelligence and agent theory technology promote mutual development and get more extensive application. It has become a popular research direction and has a broader application space in the future. On the one hand, this paper introduces the theory and characteristics of distributed artificial intelligence, on the other hand, it discusses the application of multi-agent in distributed artificial intelligence.

DISTRIBUTED ARTIFICIAL INTELLIGENCE AND ITS CHARACTERISTICS

The combination of artificial intelligence and distributed computing theory forms the concept of distributed artificial intelligence, DAI for short. The working principle of distributed artificial intelligence is to divide a complicated problem into some small problems and design systems which can solve these small problems, then, through interaction, form the systems into an integrated whole and make them work coordinately to solve original complex problem. Each system can not exist independently. It needs to coordinate with other agents to complete the task.

Distributed artificial intelligence system studies the interaction behavior of many entities, and combines with distributed idea. So, it has the following characteristics[3].

(1) It has the characteristic of distribution.

All kinds of data in distributed artificial intelligence system and its knowledge obtained through study are stored and presented by distribution. They are distributed on different nodes. Each node and path in the system can complete the calculation and information processing concurrently, and solve different problems parallelly. This can improve the efficiency of the system drastically.

(2) It has the characteristic of independence, connection and openness.

Through the connection of nodes and subsystems and the interconnection of network, distributed artificial intelligence system is convenient for system expansion and it makes the system have more openness and flexibility than a single system. Also, it can divide a general task into several independent sub tasks to reduce the complexity of nodes and subsystems, and reduce the complexity of development and processing.

(3) It has the characteristic of high efficiency, fault tolerance and coordination.

Distributed problem solving mechanisms are interconnected by computer network. It makes the cost of system communication less than the cost of the problem solving and reduces the total cost of problem solving. Distributed system has a lot of redundancy and scheduling knowledge. When there is a system failure, it can guarantee the normal operation of the system and improve system reliability just by scheduling redundant path or reducing the speed of response.

Compared with the traditional centralized processing mode, the multi-agent system emphasizes the distributed intelligent processing, which not only able to overcome the weaknesses, such as central server overload, knowledge transmission difficulty, but also to increase the use of system knowledge to improve the speed of problem solving drastically. At the same time, the parallel processing and collaborative problem solving ability of the distributed artificial intelligence can divide a complex problem into several small problems and assign them to each agent respectively to reduce the complexity of the problem as well as improve the performance and flexibility of the system. Of course, distributed artificial intelligence also has many difficulties in design. The complexity and difficulty of technology are improved greatly.

MULTI-AGENT SYSTEM

Agent

The artificial intelligence researches the realization of intelligent process in entities. And we call these entities agents. Different agents have different internal structure. There are two kinds of most extreme agents. 1) Simple agent with pure reaction mechanism. They interact freely and achieve common goals finally. 2) Complex cognitive agent. They can carry out reasoning and interaction with other agents regularly. In practice, most of the agents exist between the two situations. They not only show the behavior of reaction, also show the behavior of cognition. The multi-agent systems which

have been proposed and exploited can be classified according to the continuum shown in Figure 1, from a pure reactive system to a complex cognitive system.
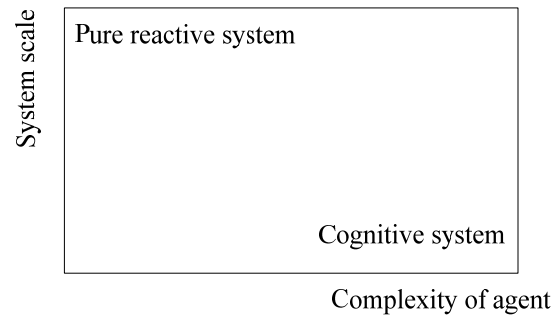

Figure 1 : Different type of agents in the field of artificial intelligence

Currently, the main research contents of the single agent design include the following aspects:
1)Selection and design of internal structure of agent.
2)Knowledge expression, reasoning based on knowledge, learning and knowledge update of agent.
3)Modeling for the outside world of agent.
4)The basic mechanisms for the interaction of agent with other agents, including communication, coordination and other aspects.

Multi-agent system

An agent is meaningful only as part of a multi-agent system. A single agent needs the support of the entire system. Each agent in the multi-agent system has a unique function. In the multi-agent system, because the task is accomplished by collaboration of agents, it is no longer the master-slave relationship of "Information - command - report" between the user and the agent, but an equal partnership.

Multi-agent systems can improve performance by learning, which is the same as a single agent. The agents can learn the knowledge and strategic behavior of other agents by learning. For example, through the knowledge learned in the process of comprehensive training, agents can learn how to deal with unforeseen emergencies. In the problem solving of collaboration, if the agents understand the environmental information and partner information, they can adjust their behavior base on the information to make the collaboration more effective among them. However, according to knowledge representation and management, agents can be divided into the following four kinds.

Agents and multi-Agent system architecture

Before the research of agent system architecture, it is necessary to study the internal structure of agent. Essentially, the internal architecture of agent is the description of the internal modules of agent and their relationship. An agent's perception, action and consultation system unit are very similar to the computer's input, storage and computational unit. But, agent is not as common as the computer; people can simulate one or more agent, even agent system in the computer [4].

There are many discussions about internal architecture of agent in the literature of studying agent. Generally, they discuss the architecture from the aspects of behavior and internal organization. From the aspect of behavior, agent architecture can be divided into cognitive agent internal architecture, reactive agent internal architecture, collaborative agent internal architecture and the hybrid agent internal architecture. The hybrid agent internal architecture is the collaborative architecture which has the characteristic of cognition and response. Figure 2 is a generic agent internal architecture which can be seen as hybrid architecture. The structure is restrained by the principle of action selection paradigm, as well as restrained by the attention, internal model, coordination and knowledge.

If we can take the internal architecture of agent as the relational schema of the agent modules, then, multi-agent system architecture can be seen as the relational schema between agents. The internal architecture of agent is to look at the agent from the microscopic perspective, but it is more important to look at it from a macroscopic perspective. This is the reason that making the research of multi-agent architecture.

In order to realize the application in industry, we often need to make sure many important parameters to develop a multi-agent system, especially the choice of infrastructure technology. But, it is difficult for people to predict its effect on subsequent design when they make the early selection. Another key technology of multi-agent system architecture is the ability to extract agent name and physical address systematically. Some architecture is supported by the message sending of content, and the other architecture send messages through the center router. The premise of all of these structures is information sharing, including the expression of shared knowledge, communication protocol or translation mechanism [5]. But in general, the agent system architecture is divided into layered architecture, the federation architecture and autonomous architecture. Figure 3 is a general layered architecture.
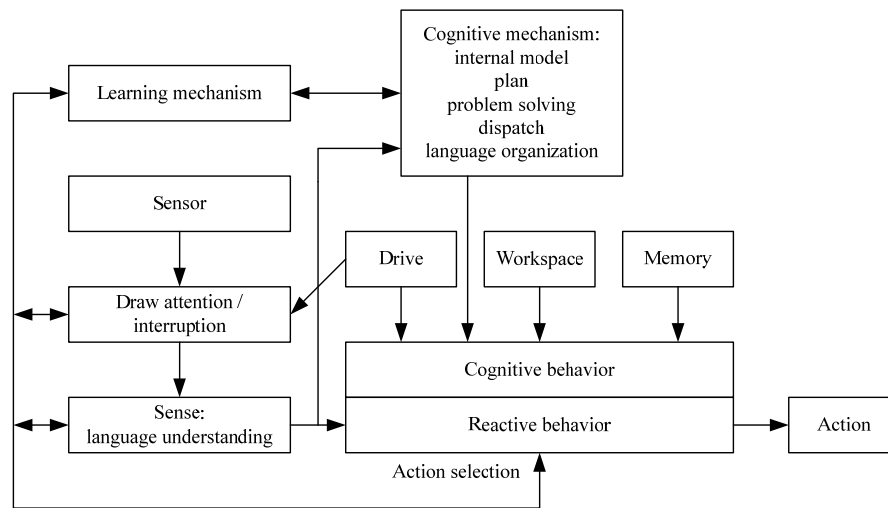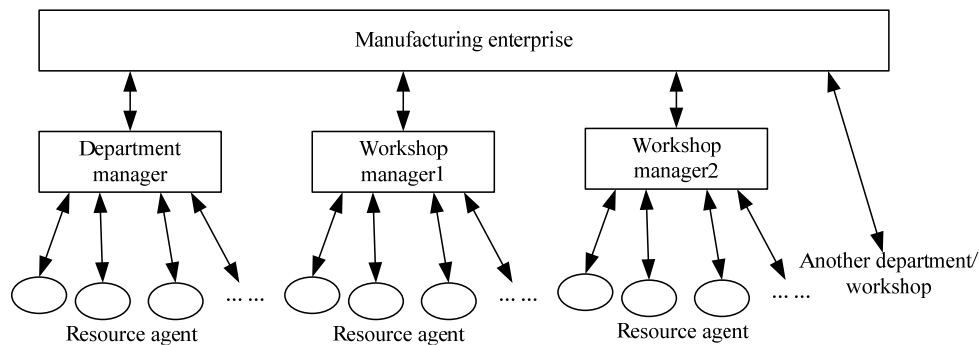
Figure 2 : General agent architecture

Figure 3 : General layered architecture

These institutions have their unique advantages. Therefore, to a certain application, we need to match the application requirements and the system performance to choose a suitable architecture.

KEY TECHNOLOGY OF MULTI-AGENT SYSTEM

Interaction and communication

Multi-agent system does not need communication all the time. In the situation of not communicating with other agents, an agent can also refer to other agents' plan and action reasonably. But communication can provide important support for the exchange of information and coordination of activities, which can make the efficient information exchange between agents. In the design of most multi-agent systems, agent makes communication by message.

In multi-agent systems, the complexity of communication depends on characteristic of agent. Reactive agent uses communication rules. When a particular state or a predetermined event occurs, the set of communication rules is triggered. We need to set the interaction protocol of agent according to various possible messages and the corresponding answer. These protocols not only set the rule of a single message, but also consider the possibility of various messages and replies. The scholars have put forward and developed many kinds of interaction protocols for the different applications. Communication and action alternate with each other, therefore, the agent must be able to generate plan. And, language and non language action are reflected in these plans.

The communication of multi-agent exists in several levels. It can be roughly divided into four categories. They are no communication or simple communication, message passing and planning transfer, information exchange of warehouse through the data sharing and advanced communication. The advanced communication in multi-agent systems is connected with the natural language understanding, Speech Act theory, conversation and other formal theory.

Coordination and consistency

The aim of multi-agent coordination process is to ensure all parts of the unsolved problem are contained in the same agent activity. So, the agent may connect each activity to the solution we design with interactive mode. This makes every part of the agent can work in the most efficient and most coordinated way, and each single agent target can be achieved by using themselves or coordinated resources.

The coordination is very important for the multi-agent system. If there is a coordination mechanism, a set of agents turns into a chaos of individual quickly. This situation is not acceptable in practical industrial process. The reasons that the multi-agent need to be coordinated have the following several aspects [6-8].

1)To prevent anarchy. The agent only has local concept, local target and the local knowledge and these ideas, goals and knowledge are likely to conflict with other agent's concept, goal and knowledge. Therefore, if no any restrain, the agent will get messy.

2)There is relationship between the behaviors of several agents.

3)Need to satisfy the global constraints.

4)No one agent has the capability, resource and information to solve the whole problem required.

5)Coordination can greatly improve the efficiency.

Cooperation

Multi-agent system has the characteristic of collaboration. But object-oriented systems, distributed computing and expert system has no the characteristic. In the concept of cooperation, many scholars have disputation and the point of view is not consistent. The definition most close to the reality is proposed by Doran. It is stated as follows: in the given multi-agent system, each agent and agent team may have one or more goals. The cooperation will exist when the behavior of each agent meets the following two conditions or one of them. There are many kinds of methods among the agents.

For the three key technologies, the interdependent relationship exists among them. Coordination may need cooperation, but the cooperation of a group of agent does not lead to coordination necessarily. Actually, it may lead to inconsistent behavior. This is because: if the agent want to cooperate successfully, it is necessary to maintain each other's model and need to develop and maintain a model for a future interaction. Coordination may also occur in the situation of the absence of cooperation. Similarly, the non-cooperation among agents does not lead to inconsistent behavior necessarily.

EXAMPLES OF MULTI-AGENT SYSTEM

This section describes the development theory of intelligent workshop and implementation method roughly. From the workshop, the traditional organization method based on the planned production is replaced by the method based on orders gradually. Also, this makes the control of production plan and scheduling link more difficult than before. The proposition of intelligent workshop is to deal with this demand.

Function realization of intelligent workshop

An intelligent workshop has many open manufacturing resources. These resources link to LAN through the computer or local intelligence controller. A workshop can realize the interconnection with enterprise's other workshops or other enterprises through the LAN and intranet. Also, it can further realize the connection with suppliers and customers. Intelligent workshop emphasizes distributed intelligence. It can achieve the following aspects:

1)It can accept the advanced file transmitted by the upper plan module, rather than the G code related with the machine tool control.

2)It can outsource production task when the equipment has fault or overload.

3)It can realize remote monitoring, diagnosis and control on the Internet.

4)It is composed by intelligent elements, such as intelligent machine, intelligent sensor, and intelligent equipment, even take the operator into consideration.

The composition of intelligent body and system structure

Intelligent workshop reference structure includes three kinds of basic agents: resource agent, product / part agent and service agent. Resource agent refers to the manufacturing equipment of workshop. The manufacturing equipment is the most basic physical configuration of intelligent workshop, usually including robot agent, machine agent, conveyor agent and operator agent. These agents connect with each other by LAN. Of course, it also can use the wireless communication mode.
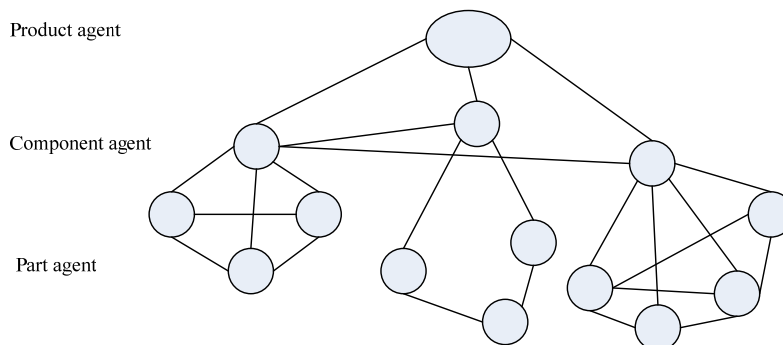

Figure 4 : Topology of product / part agent

Product / part agent is used to represent the parts and products. This kind of agent is an important entity in the intelligent workshop. Figure 4 is a topological structure of a product / part agent. When a part is processed and completed in the machine tool, part agent will move to the computer connected with the machine tool of next working procedure. Then, it will collect the processing information. After the complication of the entire part process, part agent will carry the whole data of part processing to move out the intelligent workshop. All these data are stored in the product database by part agent for future query. The service agent can be used to assist the cooperation among communication, coordination resource agent and product / part agent.

Realization of system

Figure 5 is the system architecture diagram for the multi-agent production scheduling system.
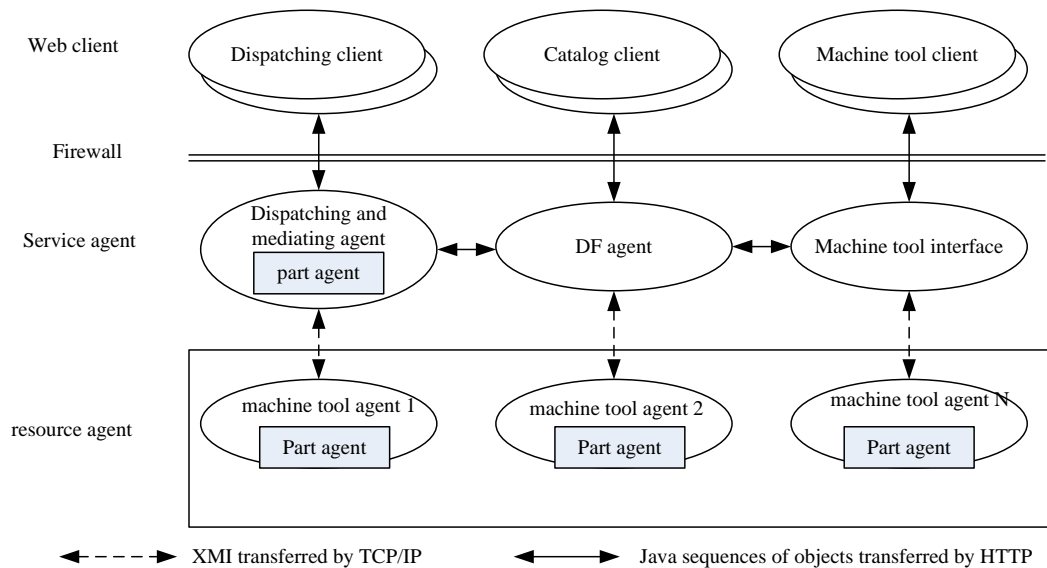

Figure 5 : System architecture diagram for multi-agent production scheduling system.

The task allocation of intelligent workshop is realized by negotiation of multi-agent. The agent can choose different protocol in negotiations according to the different situation of workshop. The system mainly includes agent and some other elements, including the three kinds of agent in the general architecture of workshop above: resource agent, service agent and product / part agent. Other elements are the user interfaces and communication of agent.

CONCLUSION

This paper introduces the related theory and method of distributed artificial intelligence, describes the multi-agent system architecture and illustrates the application of multi-agent systems in industry. Multi-agent system is a very promising method of solving practical problems in distributed artificial intelligence. However, there are still many unsolved problems in distributed artificial intelligence, for example, the application of the research findings of distributed computing theory to the study of DAI; the popularization of the distributed problem solving system and method to new areas; the study on automatic description of the task and the decomposed knowledge and structure. And there are many associations among these issues, solving a problem can promote the solution of other problems. The progress of research depends on the joint efforts from multiple perspectives and the suction of other disciplines' new concepts and new ideas. This has the vital significance to the development of industrial automation in china.

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