Research on a Novel Multi-Agent System Negotiation Strategy and Model

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***Abstract*—The communication between agents has some special requirements. One of them is asynchronous communication. Used communication sequence process (CSP) to descript a model of agents communication with shared buffer channel. The essence of this model is very suitable for the multi-agents communication, so it is a base for our next step job. Based on the communication model, explored the distributed tasks dealing method among joint intention agents and with description of relation between tasks we give a figure of agents' organization. Agents communicate with each other in this kind of organization. The semantics of agent communication is another emphasis in this paper. With the detailed description of agents' communication process, given a general agent automated negotiation protocol based on speech act theory in MAS, then we use CSP to verify this protocol has properties of safety and live ness, so prove it is logic right. At last a frame of this protocol's realization was given.**

Keywords- Automated Negotiation; Agent; Joint Intention; communication

I. INTRODUCTION

The theory of Multi-Agent Automated Negotiation involves extensive applying fields and many kinds of methods. The theory mainly lies in Argument Based Automated Negotiation, Game Theoretic Models and Heuristic Approaches [1~3]. In application, it can be divided into two categories [4], Agent's Negotiation within MAS and Self-interested between different MAS [5~7]. Those theories supporting the interior collaboration of MAS are like Self-interested, Joint Intentions and Shared Plans, no matter which are have differences, they have been working under the premise of identical intention and target of Agent within MAS. This text will discuss the Joint Intentions in Multi-Agent Automated Negotiation of MAS [8,9].

If Multi-Agent in MAS interacts successfully, there must be three conditions demanded to be satisfied as below: (1) Communication Structure, that is, how to dispatch and take over information between Agent [10]; (2) Communication Language, that is, Agent is required to understand the signification of the information; (3) Interaction Rules, that is, how to organize the conversation between Agent [12].

Regarding to the research of Agent Communication Structure, we have proposed TTMAS communication model in the previous parts. In the second section, it will be stressed to analyze Agent's asynchronous communication mechanism. As to the research of Agent Communication Language, presently there have been many abroad, like KQML, FIPA, ACL, Agent Talk, etc., so the language is not the emphasis in our text. Then, research of Interaction Rules is the second emphasis in the text. In the third part, the text will set forth the agreement of Agent Automated Negotiation and its validation. In the forth part, it illustrates and analyzes the complete frame of Agent Automated Negotiation. The fifth is the conclusion of the text.

II. AGENT COMMUNICATION MECHANISM ANALYSE

Definition 1 Agent is a status course which can accomplish the task automatically with the ability and agreement of communication, for example, P_A represents the course of Agent A.

Definition 2 The course of Agent make the Agent's ability which can be marked as $Ability_{P_A}$ and $TASK_{P_A}$ means to be able to fulfill the task.

The moving status of the static Agent in MAS can be classified as Active, Wait and Run. Agent in the Wait status will be activated after receiving the requests from other Agent and then run. Agent in Run status will negotiate with other Agent or provide services according to the Try-best principle. $State_{outer}$ stands for the Run status of Agent:

$State_{outer}::=Wait \mid Active \mid Run$

Agent's collaborating course observed from the outer MAS is the process that Agent runs in the I_{outer}=$Stae_{outer}$*

Theorem 1 In an Agent's collaborating process with Safety and Liveness, the circulation of $Wait \rightarrow Active \rightarrow Run \rightarrow Wait$ in I_{outer} will appear at least once to Agent's launch and acceptance.

Attestation: Obviously, in the circulation of $Wait \rightarrow Active \rightarrow Run \rightarrow Wait$, if any one part of Agent can not fulfill the circulation, it means something happened unexpectedly cause the deadlock or livelock to the system during the collaborating process, so the theorem attested.

More and more application systems ask both corresponding sides of each other in a position to realize asynchronous communication mode. As a self-contained MAS

communication structure, it is not only in a position to realize Agent's synchronous communication， but able to realize asynchronous communication. Miner's π figuring has realized transfer calculations by communication passage, which makes out that we can utilize Agent's asynchronous communication mode to realize synchronous[13]. The asynchronous communication's ideal mode means that both corresponding sides own one infinite buffer queue [14]. However, it is unpractical to deploy such infinite buffer queue to each Agent, whereas to share buffer channel may realize Agent's transfer between asynchronous communication and synchronous communication better.

Definition 3 Buffer channel C is such an Agent which set independent state switch and message buffer to all its relevant Agents and transmit messages for these Agents.

Utilizing buffer channel may realize manifold asynchronous communication modes. Introductions of transmit message *m* through buffer channel as below

$$P_A = Wait \xrightarrow{o} Active \rightarrow Outer?\, x \rightarrow C!\ (m) \rightarrow Wait$$

$$P_C = Wait \rightarrow C?\ \ (m) \rightarrow \text{if}(P_B\ .State_{outer} = Wait)\ then\ C!(m) \rightarrow Wait\ else\ Wait$$

$$P_B = Wait \xrightarrow{\bar{o}} Active \rightarrow C?\ (m) \bullet Wait$$

The above process shows that Agent can realize asynchronous communication between Agents by use buffer passage. P_C stands for buffer channel tenor.

The synchronous communication between Agents asks Agents themselves shall be clear about each other's corresponding location. If a MAS system owning N (numerous) Agents would like to realize point-to-point communication between Agents, there will be N^2 channels needed to set up, of which so many will complicate the realization of Agent extremely. Using shared buffer channel can be good for realizing channel's transmission between Agents.

Agent negotiation process described in the following text shall work according to the above communication mechanism which ensures Agent to communicate using asynchronous or synchronous communication modes and reduce complexity of its communication system.

III. MAS INTERIOR AGENT COOPERATION MODE

A. Agent cooperating principle

When Multi-Agent in MAS begins cooperation, for the reason that there is a conform joint intension between Agent, the process of Multi-Agent in MAS works according to the principal of "From each according to his ability, abide by the law and behave oneself", that is, each Agent is trying its best to cooperated with other Agent [15].

The cooperation between Agents is aimed at fulfilling a certain tasks. Because tasks can be divided into different but related sub tasks, the tasks from Agent's point of view can be described as following: a material task can be regarded as sub-tasks' assembling depending on different ability of Agent in MAS. Combining divided-task-oriented Agent in compliance with sub tasks will be in position to form a furcation tree of k($k \geqslant 2$). Relation between sub tasks is relation with or to time sequence. Agent's organizing relation is determined by the relation between tasks. Description of sub tasks as below:

（1）The sequential relationship of the tasks（＜）, manifests that Agent B's task can not be begun before fulfilling Agent A's task. Formalization to be described below:

$$TASK_{P_A} < TASK_{P_B} | = P_A;\ P_B$$

Thereinto：TASK_{P_A} and TASK_{P_B} respectively means the start-up tenor P_A and P_B of Agent A and Agent B are used to fulfill tasks.

（2）The relation of "AND" between tasks （V）, indicates that Agent A and Agent B perform simultaneously sub task P_A and P_B. After completing the sub tasks, Agent C begins their common and subsequential task P_C. Formalization described as below:

$$\text{TASK}_{P_A} \vee \text{TASK}_{P_B} | = (P_A \parallel P_B) < \text{TASK}_{P_C} | = (P_A \parallel P_B) < P_C$$

（3）The relation of "OR" between tasks （∧）, indicates that Agent A and Agent B with the relation of "OR" perform simultaneously sub task P_A and P_B, no matter which is fulfilled first, Agent C can begin its subsequential task P_C. Formalization described as below:

$$\text{TASK}_{P_A} \wedge \text{TASK}_{P_B} | = (P_A < \text{TASK}_{P_C}) \parallel (P_B < \text{TASK}_{P_C}) | = (P_A < P_C) \parallel (P_B < P_C)$$

From the above mentioned: MAS is a task processing distributive system. The Agent's ability can be realized by its corresponding tenor. The relations between tasks in MAS have determined that Agent is organized according to its dendriform communication topology which is the precondition for Agent's automatic negotiation.

B. Automatic negotiation in agent protocol

Agent automatic negotiation is the main method for multi-Agent to negotiate, which focus on three aspects lieing in negotiation protocol, negotiation object and negotiation policy. Negotiation protocol and negotiation object act as the textual points, but the negotiation policy is clampinged how to look for in Agent each from of negotiation space best in order to reach consistence, concretion content visible literature cited.

Present hypotheses 1 to ensure negotiation agent could each other have partner faith in against due to MAS interior Agent according to Try-Best principle proceed synergic, furthermore MAS possess concurrent combine intent.

Hypotheses 1 Negotiation Agent knows each other in negotiation policy.

Be on the negotiation with the result that decision agent toward internetwork communication negotiatory condition of Agent automatic negotiatory course mission due to specific assignment require different communication quality guarantee AND specific network insurance. Text take mission negotiation AND internetwork communication negotiation as agent automatism negotiation in process two phase.

Definition 4 MAS interior agent automatic negotiation course could include two phases. The first phase is based on multi-Agent automatic negotiation whose negotiation object includes task starting time, task ending time and the relation of the tasks; The second phase is the negotiation of Agent's communicating conditions whose negotiation object include corresponding security policy and network service quality（Q_OS）.

According to the top analysis talks about with the correlative language behavior academic theories, we say the Agent automatic negotiation correspondnce in the procedure to state row word certain for: request, promise, refuse, advise, counter advise. In view of agreement presence overtime event and agent unsolicited message transmission, so increase overtime（timeout）status and inform （inform）state row word that. Communication protocol engine of the communication process state as follows of the agent:

$State_{inner}$ ::=*Started*| *Requested* | *Accepted* | *Refused* | *Promised* | *Informed* | *Advised* | *CAd-vised* | *Timeout* | *Stopped*

See Fig.1: Agent automatic negotiation protocol can be divided into information transmission layer, buffer channel layer and Agent negotiation protocol layer from bottom to top, of which buffer channel layer C is one of the needed layers between Agents to realize asynchronous communication. If it will realize point-to-point synchronous communication between Agents, it can do communication directly through channel C. As to the description of Agent automatic negotiation, it mostly focus on Agent negotiation protocol layer, while for the other layers, it only describes their services and running environment in brief. In essence, the function of Agent negotiation protocol layer is the description of process.

(1) The service provided by each protocol layer
See Fig.1:

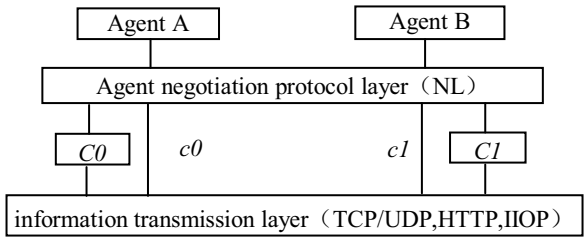

Figure 1. Agent automatic negotiation protocol model

a. Information transmission layer: being in position to transmit information data between Agents in sequential way and correctly;

b. Buffering channel C0 and C1 layer: providing Agent automatic negotiation layer with the services described;

c. Agent automatic negotiation protocol layer: supplying Agent with credibility, efficient negotiation control and policy.

(2) Description of Agent negotiation protocol layer functions:

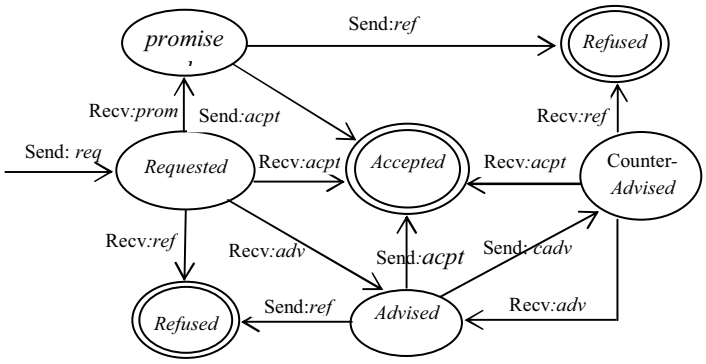

Figure 2. Agent negotiation protocol statement vicissitude figure

Fig.2 receive agreement on state vicissitude chart， from the view of agent negotiation starter Among them: arrowhead direction are the flow direction of Agent information; The Recv means a certain message in roger in right connecting; send stand for exactness forward to some information； Following behind the Recv/ Send is a message type, both state vicissitude picture with state refused and accepted implication negotiatory amphi-with the result that； negotiation the rough and smooth， along with it show that negotiatory terminal status.

The Agent A describe with Agent B whole negotiation procedural not formal as follows: Agent A first of all dispatch negotiation beg of Agent B received solicit aback, toward request message proceed analyses, could as per three strain scene dispose to： the first thing, in the event of Agent B receivability the solicit of Agent A, those Agent B to Agent A dispatch take send , else dispatch thumb advise， down through upon, the service request block mode， of the such negotiation scene as conventional C / S. the second thing, Provide some Agent B can provide serve of instruct, but because of the restrict of the resource of system can't very much the serve, so the Agent B can put forward to Agent A the serve promises, the Agent A handles Agent B the commitment of serve can proceed very much: Reject or accept. the third thing, The Agent B thinks after analyzing the Agent A request Agent A some items modification within request empress, can satisfy the Agent A request still, like this Agent B after proceeding Agent A some items within request to modification, conduct and actions the suggestion sends out to the Agent A.

(3) Agent consults the working environment that the protocol needs

a. Agent consult agreement lower floor information transmission layer of layer can is it is it spread mistake travel the mistake to the upper strata agreement to get to measure

automatically. Namely the information transmission layer has fault-tolerant ability.

b. The array of every part of one layer of news transmitted of the information transmission should be correct.

Because the protocol in information transmission layer is standard, this text assumed information transmission layer it transmits is reliable. This is the basic demand of Agent Negotiation Protocol in working.

C. The verification of agent automatic negotiation protocol

Utilizing process algebra to carry out formalization of communication protocol not only can state logic structure and time sequence nature of the protocol narrowly, but also is favorable to verify the protocol. The nature of the protocol includes Liveness and Safety. In the protocol system of liveness, its process algebra expression must own the recursion characteristic from initial state to the passing. If protocol stops executing a certain event and is unable to go on, the system will be dead locked. If protocol executes some certain events circularly and infinitely but is unable to return to initial state, the system will be alive locked. The system without dead lock or alive lock will be safe. According to the above statement, the definition put forth as below:

Contain the protocol system extremely locking the state, including STOP process in its CSP expression formula.

Contain alive protocol system that lock, its CSP expression formula will certainly include part exported to have pass ring of returning.

Consider protocol JIAANP =| | | Pi =(P1 | | | P2 | | | … | | | Pn) =| | | (PS | | PR), because will not carry on communication directly between Pi and Pj (i≠j) , can think that they are separate , namely can store in and lock or live and lock. So we may prove that if there is dead lock or alive lock appeared between promoter process P_S and acceptor process P_R of Negotiation.

Considering three kinds of different conversation scene Q1 in agreement JIAANP, Q2 , and Q3, among them, the simple message is sent and received in the execution course of Q1 and Q2, not forming circulation in the state changes picture of the agreement, so they will not be formed and extremely locked or lived the lock. There is proposing and counter proposal circulation in the execution course of Q3, it carries out course and may be formed and locked and lived and locked very much, the complexity because transmit for the agreement overtime proves the difficulty brought for the agreement, so we suppose: The transmission of the network is reliable , the feedback between Agent is in time, namely, logic exactness of the agreement that the prerequisite without incident in overtime comes down to prove in the agreement.

IV. CONCLUSIONS

This text provides a common and communication-based Agent cooperation mode by studying mutual behavior of Agent cooperation. The text also uses some effective format ways to depict automatic negotiation protocol of Agent process and verify the validity of the protocol's logic. Finally, the text makes an implementation frame for this agreement. While using blackboard mode to realize buffer channel in this implementation frame, it provides a deployed agreement stack extra and at last it presents performance analysis and expandable analysis. In addition, as to negotiation between Agent in MAS, because the advantage difference of Agent group negotiating with Agent which has a conform joint intension has great differences on negotiation principle and strategy, the self-interested Agent's negotiation agreement between MAS is our next work under research.

ACKNOWLEDGMENT

This paper is supported by the Society Science Foundation of Hunan Province of China No. 07YBB239, and the Natural Science Foundation of Hunan Province of China No. 06JJ2033.

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