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A Survey of Logics Concerning Belief Revision and Update by Agent Communication

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An agent is a computer system that can autonomously make decisions suitable for a particular purpose, is characterized by the reaction to the environment, autonomy, goal-oriented, and persistence. It is supposed that applications of agent technology are software which can autonomously make decisions for the purpose of supporting works of human beings (ex: distributed computing, man-machine interface), an implementation of robots (software, hardware) , simulations concerning to the development of language, individual behavior of human being, social decision making, in wide-ranging various fields On the other hand, due to its wide range of application areas, the studies of agent are done in the diverse disciplines, such as philosophy, mathematics, engineering, economics, finance and so on. This makes it difficult to grasp the whole trends of researches about agent or multi-agent technology.

In this survey, towards the future application for multi-agent system, we conduct a survey of researches about the logic of revising or updating the knowledge and belief of the agent or the formalization of communication among agents. We've intended to grasp the whole trend in these disciplines. This survey is composed of the following content. First of all, we organized the rough and historical flow of researches for the logics of agents that are relevant to this survey's main target area. Second, we describe the

implementation of a survey and it ' s results. Third, based on the trend obtained from our observations, we picked up several research issues and investigated their results and challenges.

For the rough and historical flow of research about the logics of the agents, we investigated in view of the three categories. These are the logics about knowledge of agents, the logics of actions of agents and the other categories. Modern researches about artificial intelligence, or about an agent have begun in 1950s. In these researches about knowledge and belief , there are variations of modal logics such as Temporal Logic which is the logic about time and modality, epistemic logic dealing with the states of knowledge and belief, or it's dynamic version, Dynamic Epistemic Logic which can express the dynamic changes of epistemic states. In researches about an action of an agent, there are logics such as BDI Logic which modeled a rational agent, Alternating-time Temporal Logic which is extension of Branching-time Temporal Logic and so on.

In this survey, we checked the major conferences, workshops, journals of the past 10 years (since 2003), concerning to the logics of knowledge and belief in multi-agent systems. And we conducted an investigation of these papers. We distinguished about 150 papers according to keywords related to the target area such as 'agent', 'multi-agent (system)', 'logic', 'knowledge and belief update', 'belief revision', 'communication' and the like. Examples of the survey's target documents are belows.

- Workshops and Symposium (CLIMA, ISMIS etc.)

- Conference (IJCAI, AAMAS, AiML, IEEE/WIC/ACM, ECAI, etc.)

- Journal(Journal of Autonomous Agents and Multi-Agent Systems, Journal of Logic and Computation, Journal of Logic, Language and Information, etc.)

We selected tens of papers which appear to be related closely to the theme of this survey, among the about 150 papers thus collected. Then we classified their categories and summarized their keywords. In the fields of logics of knowledge and belief, we observed trends of attempting to deploy logics of belief change to multiple agents or to represent the change of knowledge by dynamic logics which can deal with knowledge and fact or action, or

to expand the logics which are for the single agent to multi-agent system. And in the fields of logics of action, we observed trends, such as an attempt to consider the agent 's knowledge about the other agent's knowledge in the decision making.

In addition to this classification, we could find standing keywords, in the papers about knowledge of agent, such as 'Dynamic Epistemic Logic', 'Public Announcement' which can deal with the action in addition to the knowledge. Or 'AGM', 'internal' which indicate the expansion of logics about belief change for corresponding to multi-agent. Or 'Common knowledge' which represents the knowledge of multi-agent system or agent group. And in the paper of actions of agents, we could find the keywords such as 'Coalition Logic', 'Alternating-time Temporal Logic', 'norms' these are used for describing the ability of a group of agents to accomplish a goal of the group, 'Answer Set Programming' which is often used for the implementation of decision making in multi-agent system, 'speculative' which indicates the judgement in an uncertain environment.

In addition to these summarizes of whole trends, we picked up some research issues which are supposed to have closed relations to these trends, and investigated these individual issues. These are below.

-Attempt of extension of logics of belief revision to fit the multi-agent system

In these issues, in some papers, internal possible worlds model is used for expressing the world from the view of each agent, and in these world traditional belief revision theory can be used. And in some paper, Linear Algebra is used to express multi-agent's knowledge state change.

-Attempt of expansion of logic for describing the ability of the group of agents

CL (Coalition Logic), ATL for (Alternating-time Temporal Logic) are relatively new logics, and in the papers concerning to this issue, attempts of expanding and adjusting to the real world can be observed.

-Researches on norms which achieve the cooperative behavior of multi-agent

As a means to effectively realize the coordinated action, study of the system including norms have been carried out in the form of expanding the Deontic Logic and other logics such as Propositional Dynamic Logic

etc.

-Dynamics in Epistemic Logic

In papers concerning to this issue, we can observe an adoption of the new concepts such as awareness, assignment. With these concept, new logics, which are constructed on the basis of epistemic logic, are focusing on the dynamic changes of the epistemic states of agents.

Finally we summarized the trends of researches about the logics concerning to multi-agent system as a conclusion.