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AN ONTOLOGY-BASED APPROACH FOR EXPERT AND KNOWLEDGE MINING IN COMPLEX MULTI-AGENT SYSTEMS

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Abstract

Complex problems require diverse expertise and multiple techniques to solve. In order to solve such problems, complex multi-agent systems include numbers of heterogeneous agents, which may include both of human experts and autonomous agents, to work together toward some complex problems. Most complex multi-agent systems are working in open domains. Due to heterogeneities and dynamic working environments, expertise and capabilities of agents might not be well estimated and presented in the system. Therefore, how to discover useful knowledge from human and autonomous experts, make more accurate estimation for experts' capabilities and find out suitable expert(s) to solve incoming problems ("Expert Mining") are important research issues in the area of multi-agent system. In this paper, we introduce an ontology-based approach for knowledge and expert mining in hybrid multi-agent systems. Here, ontologies are hired to describe knowledge of the system. Knowledge and expert mining processes are executed as the system handle incoming problems. In this approach, we try to embed more self-learning and self-adjusting abilities in the system, and make it more suitable for high-ability hetero-generous experts and open environments.

Keywords: *knowledge discovery, knowledge mining, expert mining, multi-agent system*

1. Introduction

Nowadays, many complex problems require diverse expertise and multiple techniques. In order to solve such problems, numbers of heterogeneous agents [8, 9], which may include both of human experts and autonomous agents, are sometimes required to work together in some open domains [1, 5]. In these complex domains, agents' number, experiences and expertise may not be stable. Also, due to heterogeneities, expertise and capabilities of agents might not be well estimated by the system. In this case, how to dig out useful knowledge from human and autonomous experts, make more accurate estimation for experts' capabilities and find out suitable expert(s) to solve incoming problems is an important research issue in multiple areas, which include multi-agent systems, distributed information retrieval, distributed problem solving, data-mining, etc.

In this paper, we introduce an ontology-based approach for knowledge and expert mining [6], which is to discover specialized knowledge and expertise of

experts, in hybrid multi-agent systems. In this approach, ontologies are used to describe knowledge of the system. The knowledge and expert mining, which is a life-time long process, will be performed through update the ontology of the system. The knowledge and expert mining are processed as the experts of the system solve incoming problems.

The rest of the paper is organized as follows. In Section 2, we present some basic concepts of multi-agent systems (MASs) and complex multi-agent systems (CMASs). In Section 3, the concept of ontology and ontology of the CMAS is introduced. We propose the ontology-based approach in Section 4. Finally, the conclusion is given in Section 5.

2. Experts and Knowledge in Complex Multi-agent Systems

Knowledge discovery is a preliminary and an important process for multi-agent system (MAS) applications. It mainly contains two processes:

1. Initial understanding the problem domain and describing incoming problems in an agent-readable format;
2. Understanding agents' capabilities and expertises.

Knowledge discovery for MASs with heterogenous agents is more difficult then common MASs. Here, we define a MAS with hybrid agents (human and autonomous agents) as a complex multi-agent system (CMAS). As a CMAS, agents of the system could be from various originations and have various expertises, knowledge and capabilities. This makes it hard to describe agents' knowledge clearly in a particular formal way. Agents of a CMAS are experts in some particular area(s). They not only possess special knowledge but also expertise and experience to solve some particular problems. Take medical diagnosis as an example, various human experts or/and diagnose-agents from different branches are grouped together to give proper diagnosis for patients. Each agent has its own knowledge, experience and expertise of own branch area. However, some of their knowledge (especially for human experts) is hard to be formally described or even discovered. Through several preliminary knowledge mining steps, it is impossible to find out and describe all knowledge of every agent in the system. Furthermore, some kinds of information, such as experience, even might not be well realized by the agent itself.

Comparing with common agents, an expert is more sophistic. It has ability to check, modify and update knowledge according to its own expertise and experience. It has strong learning ability to improve its capability (accumulate experience). On the other hand, experts also bring dynamics to the system. As an expert improves its knowledge and ability, the overall capability and domain knowledge of the system should also be modified (see Figure 1).

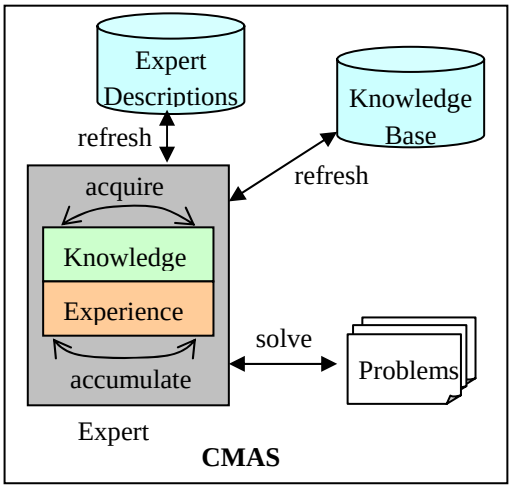

Figure 1. Expert in a CMAS

For a CMAS, expert discovery is another important process. This process is to estimate expertise of experts, category experts into proper areas and find out suitable experts for incoming tasks.

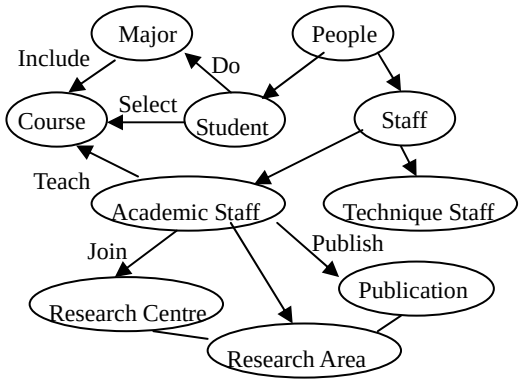

Figure 2. Example of Ontology

3. Ontology

To facilitate knowledge and expert discovery in CMASs, in this research, we establish ontology to describe conceptually concise basis of system knowledge.

3.1 Ontology in MASs

In the area of MASs, an ontology is a description of the concepts, relationships and constraints that can exist for an agent/expert or a community of agents/experts [2, 4, 10]. It can provide not only a description for knowledge contents but also relationships between different knowledge. Ontologies in MASs normally specify conceptualization of a domain in terms of concepts. Each concept represents a class for a specific set of entities. In an ontology, the concepts are typically organized into a taxonomy tree, and each node of the tree represents a concept. Concepts are linked together by means of their semantic relationships. In Figure 2, we give a simple example of ontology that describes "University Department". In this example, nodes represent concepts of the domain and arrows show the relationships between these concepts.

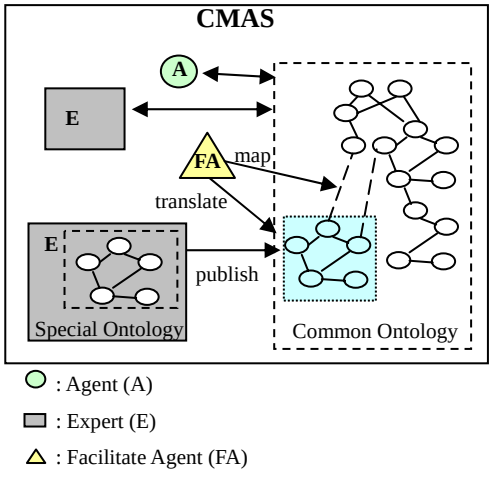

Figure 3. Common and Special Ontology in a CMAS

Ontologies of a MAS can be classified as common ontology and special ontology. Common ontology is used to describe domain knowledge of the system. It is written in a formal language which can be understood by all agents of the system. Especially in CMAS, some sophistic agents (experts) may have unshared ontology for its specialized area. This kind of ontology is defined as special ontology. A special ontology is not published in the system and could be written in some specific format that only can be understood by the expert. An expert can also publish its special ontology to the system. However, the special ontology must be translated into the common language and map into common ontology of the system before it is published. This process can be executed by facilitate agents of the system (see Figure 3).

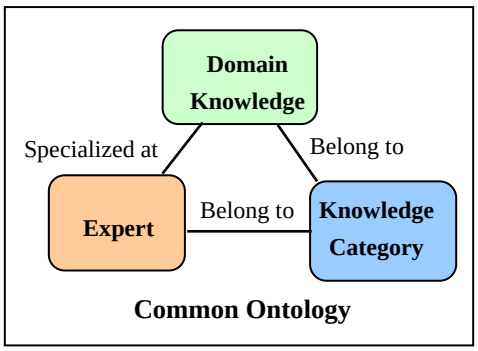

Figure 4. Including Experts in System Common Ontology

3.2 Including Experts in Common Ontology

Experts bring dynamics and difficulties for knowledge discovery in CMASs. On the other hand, they are also the most important part of a CMAS. Whether the knowledge of experts are discovered and applied properly is the key benchmark to evaluate a CMAS. To facilitate exploring experts' knowledge and expertise, in this research, we include experts into the common ontology of the CMAS. Through this way, experts will exist in the common ontology as a class of knowledge and have links with other domain knowledge of the system (see Figure 4). This brings conveniences for task allocation and knowledge discovery. Through an expert's category and linked knowledge, we can find more effective and pertinent way to achieve expert mining.

Same as other common ontologies, an expert is also described in a unified/formal format. In this research, we define three compulsory properties for concept expert: specialized area, expertise knowledge and experience value. Figure 5 shows a simple example of expert ontology that describes a gynecologist. The experience of an expert represents how good the expert is. Experience value must be estimated by a unified rule among the system.

Expert name: Dr. Munez;
Specialist Area: gynecologist;
Expertise Knowledge: gynaecology;
Experience: 58;

Figure 5. Expert Ontology Example

4. Approach for Knowledge and Expert Discovery

Many current CMAS applications focus on how to extract experts' special rules and convert these rules as system expertise. However, most current CMAS applications have some limitations. Firstly, if knowledge extraction is performed without some particular purpose, it is very hard to say whether the extracted knowledge is useful for the system. Secondly, most of these kind approaches will meet the difficulty to extract knowledge from heterogenous experts. Even if the CMAS can perform knowledge translation between several knowledge representation formats (languages), it is still hard to predict knowledge representation format of the incoming expert especially in an open environment. Finally, most current CMAS applications take expert mining as a one-time process. However, since experts have high learning ability and may work in open environments, knowledge, expertises and experiences of experts are updated frequently. Hence, the (one-time) mining result might be not accurate and complete. Considering these limitations, in this section, we present an ontology-based approach for knowledge and expert discovery in CMASs.

4.1 Expert Estimation and Description

When a new expert joins a CMAS, the fist step to include it into the system is to estimate and describe it in an expert ontology.

There are different ways to estimate machine and human experts. For an agent expert, the estimation is achieved through some data mining or AI methods [3, 7]. Estimating a human expert could be achieved through interviews or surveys. Some CMAS applications take expert estimation is the only step to discover experts' knowledge. However, in this approach, expert estimation is the preliminary step to include a new expect into the system. This process is to draw an overall image of the new expert and find some related knowledge and category for it.

4.2 Task Processing and Ontology Update

In this approach, expert mining is a "life time" process. It will be processed as incoming tasks are solved by experts of the system (see Figure 6). Here, we assume that all incoming tasks/problems can be described as knowledge format of the system. Then, the CMAS will be able to map it with the common ontology to the system. The ontology mapping is to put the task in proper categories and explore related knowledge in the ontology. It can have three possible results:

a. The task can be mapped and the solution for the task can be found in the current common ontology. In this case, the incoming task might be achieved in the system before, and current common ontology is sufficient to provide solution. The common ontology and knowledge will not be refreshed.

b. The task can be mapped but the solution can not be found in the current common ontology. Normally, this situation occurs when same kind of tasks has been solved in the CMAS, but the task is different with previous (solved) tasks. Another possibility is that experts in the system have solved this kind of problems before, but they did not publish their solutions in the system. In this case, the CMAS will allocate experts that are in the same category of the task to solve the task. After the task has been solved, the system will

modify the experience value of the expert in the common ontology.

c. The task can not be mapped in current common ontology, which means the task has never been done by the system, and there is no suitable category can be found. In this case, the system will broadcast the task description to all experts of the system and see whether there exist any experts who can solve this task. If no expert gives response, the task will be rejected by the system. If there is an expert who can do the task, the system will allocate the task to it. After the task is solved, the system will set up links between the task and the expert in the common ontology. Also, the expert can publish its expertise and knowledge in the system.

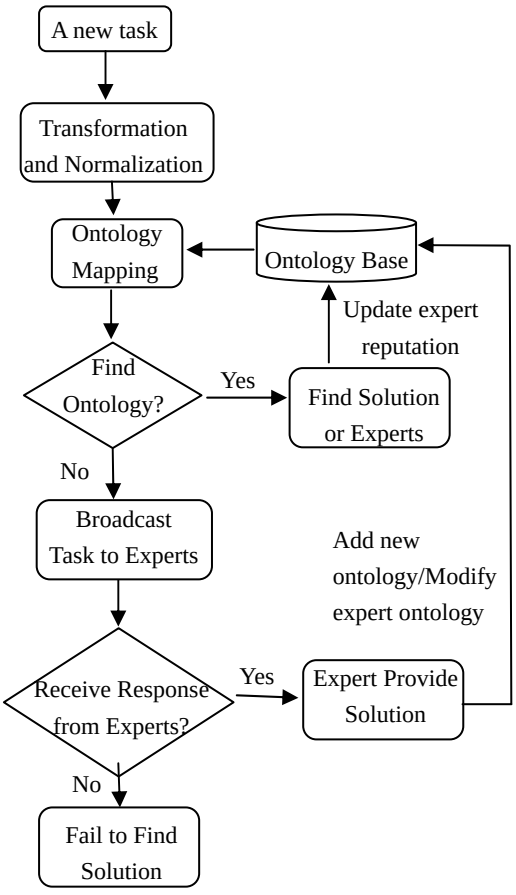

Figure 6. Ontology-Based Task Processing

4.3 Experts' Experience

In a CMAS, there may have more than one experts in the same area. These experts may have conflicts on their special knowledge, expertises and solutions. In this case, the system will choose the expert with higher experience value. The experience value can be considered as the reputation of experts. It is calculated according to the previous task execution result of the expert. An expert's experience value could be increased or decreased depending on the performance of a task.

Another case that the system may need to estimate the reputation of an expert is when the expert wants to refresh the common knowledge of the system. In this case, the system needs to evaluate whether the expert is specialized in that area through estimating its experience value. If the value is greater than the specialist threshold, the system will allow it to publish the knowledge. If the value is medium, the system will find out other experts in the area and collect suggestion from them. The knowledge refresh request will be rejected if its experience value is too low.

5. Conclusion

In conclusion, knowledge and expert discovery processes in CMASs are limited due to agent heterogeneity and open dynamic domain. In this paper, we use ontology to manage and structure the domain knowledge of a CMAS and embed experts into the common ontology of the system. Ontology brings conveniences for task allocation and knowledge discovery. Through an expert's position in the common ontology, we can find more effective and pertinent way to achieve expert mining. In this approach, expert mining is a "life time" process that is executed as incoming tasks are solved by experts. Through this approach, we try to add more self-learning and self-adjusting abilities to the CMAS, and make it more suitable for high-ability heterogeneous experts and open environments.

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