Coalition Representation in Ontology Using Various Type of Logic

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Abstract: Coalition of agents is a typical product of a negotiation between agents, which has been addressed by many research publications. These negotiation processes usually solve very complex problems in the field of artificial intelligence; thus an experience management system for reusing of gathered knowledge should be essential. This paper addresses issues in a representation of a coalition as an experience item in the experience system utilizing an ontology and several types of first order logic used to model multiagent systems. Also, an implementation of ontology using Protégé, which is a graphical software tool for modeling of ontologies, is presented.

Keywords: agent coalition, ontology, experience management

1 Introduction

Coalition formation in a multi-agent system is a very important problem which has been investigated for many years and numerous articles, which address many solutions, have been published. After several years of research, two main research approaches can be recognized. One is based on a negotiation between agents and another one utilizes a computational centralistic approach [3] [9] [5] [4]. However, these two attitudes results in the same optimal or suboptimal solution which can solve complex problems typical for artificial intelligence. The pros and cons of both approaches are briefly summarized in [12].

In the agent coalition formation environment, the following two emerging questions have to be solved:

- an automatic search for right protocols or algorithms from a coalition formation knowledge base, which suits the particular application's domain,

- an automatic adaptation of the agent's protocol to the prescribed protocol in the specific agent application, such as e-commerce, e-work, e-business, etc. [10] [2].

The first objective is not a simple decision process. However, an agent also has to automatically recognize, learn and utilize protocols. The second objective concentrates on adaptation of the agent's protocol to a new one which is in the same protocol family. This objective allows agents to roam free through the small precisely defined electronic network. However, the first objective can give stronger capability to an agent - to roam through the electronic network without any boundaries. Both questions have to address the problem of storing agent's results in an ontology for any further reuse, which is very important for learning and refining a knowledge system used in the application. In this paper, we shall concentrate on using an ontological representation of coalitions in knowledge system as experience gathered by an agent during a negotiation or computation process.

This paper is divided into six sections as follows. The first section is an introduction to this paper. Afterwards, an introduction of experience management is presented. The third and fourth section concentrates on coalition representation using first-order logics. The next section encompasses examples of coalition representation from logic point view. The last section presents layered ontology which might be used in experience management. The article is closed with conclusions and an acknowledgement.

2 Experience Management

The experience management system (EMS) is a subclass of a knowledge management system, which is the crucial part of each intelligent system. This management type utilizes knowledge gathered so far, known as experience in solving new situations which are from the same problem domain. An experience is defined as pair of a situation and its solution, which is usually stored in an ontology or in a relation database. Such repository of experience is known as experience base. Description of the situation and the solution vary in each application. In general, descriptions of such elements can be divided into the following four types, namely attribute-value, tree, logical and general description. Attribute-value description is a well known representation of objects defined as set of attributes and their values. If each object in the environment has the same set of attributes, then the environment is called homogeneous; otherwise the environment is heterogeneous [8]. If each attribute has a default value defined, then the environment is homogeneous. Comparison of two objects in a heterogeneous environment is not as straightforward as in a homogeneous one [8]. The graph experience's description may be used to describe a program which is

the result of genetic programming and none additional transformation has to be used. Similarity measuring of such experience is still opened issue [13]. The third experience description operates with various types of logics, especially first-order logic which is used in modeling of agent system [1] [11] [6] [7]. The last general modeling approach of experience in knowledge system is usually used in the case where none of the previously mentioned approaches can be used. This approach is the worst alternative, because new adaptation algorithms and similarity measurement have to be developed each time it is implemented. In this alternative reusing is a very important issue.

Experience management system encompasses the following processes [13]: to collect user requirements, to search for the most similar situation stored in experience base, to adapt the solution of old similar situation new situation using adaptation rules or process, to present solution candidate to the user and to apply solution, to collect feedback from the user, to enter new experience into the experience base.

It is obvious that EMS has to communicate with an external entity such as a user or a computer system, which evaluates the solution candidate for the new situation. Note that this feedback is optional, but its existence improves experience management quality, because if the solution candidate is not accepted by the entity, it has to be reprocessed. Existence of the external entity causes that EMS is a decision support system, whose main role is to offer a new solution candidate rather than to execute them. On the contrary, if the evaluation of a new solution candidate is implemented in EMS, then it can be used as a decision system.

3 Context and Objective Definition

Experience item consists of two part; the first describes a specific problem and the second part the solution of the problem [13]. From a coalition point of view, the problem can be described by a context of a coalition and an objective of the coalition. The context of the coalition formation problem is a description of the environment, where the formation process takes place. Note that the coalition formation process is context sensitive, which means if context is changed, then the result of the coalition formation can also be changed. The objective of the coalition is important for the coalition formation algorithm, which gives the meaning and the direction to the coalition. Experience problem definition using the context and the objective is sufficient for similarity measurements. These two elements precisely define the environment and input arguments for the coalition formation process.

Numerous logics can be used to describe multi-agent system. However, the aim of this approach is not to describe the whole MAS; only a set of agents, which are

considered in the formation process, has to be defined. Other parts of knowledge system have to describe whole MAS and to maintain more specific information which is static from the coalition formation algorithm point of view, such as: agent relations, system capabilities, etc. Comparison of several logics such as coalition logic for propositional control [11], concurrent dynamic epistemic logic [6] and alternative-time temporal (epistemic) logic [1], results in common description of a set of agents in multi-agent system, which is addressed in this article. According to the previously mentioned assumption, the problem part of experience item is described by the following formula

$$\langle\langle C \rangle\rangle o, \tag{1}$$

where $C \subseteq Ag$ is the subset of all agents in the MAS and $o \in O$ denotes an objective from the set of all objectives feasible for the MAS. Objective is a proposition which describes an intended "mental" state of the system. If the defined proposition o becomes true, then the mental state has been reached.

Set of objectives is dependent on a multi-agent system description. If ATL logic is taken into account, then the objective of the coalition can be any state of the MAS. However, if CL-PC is considered, then the objective is any propositional formula which makes sense according to the MAS.

4 Coalition Representation

The previous section models the problem part of the experience item in knowledge base. This section concentrates on the solution part of the experience item, which consists of inner and outer representation of the coalition which is the solution of the coalition formation process. Outer description is a global representation of the coalition. This representation is important for agents in and outside. Agents from the coalition can use outer representation for querying their partners. Agents outside the coalition can use outer representation for identifying the coalition and learning. Inner representation of the coalition is mostly important for agents from the coalition, because it includes optimal plan of the coalition which guides the coalition's agents to its objectives.

Outer definition of the coalition is the same as description of any subset of agents in the multi-agent system. Thus, the same description of the coalition is used as in the previous equation (1):

$$\langle\langle Col \rangle\rangle, \tag{2}$$

where $Col \subseteq Ag$ denotes the coalition of the agent, which is the subset of all agents in the multi-agent system. From the principles of coalition formation process, the following rule can be denoted:

$$Col \subseteq C, \tag{3}$$

where C represents the context of the experience item.

Inner coalition's description is more complex than outer description. This description describes coalition's optimal plan which results in fulfilling of objectives. For these purposes, logics for description of dynamics in MAS may be used, such as ATL, CL-PC or CDEL. Each of these logics defines dynamics of the MAS from a different point of view. ATL manipulates with propositions which are hardly connected to states and transitions in the MAS. CL-PC considers controlling of propositions defined in the MAS. CL-PC's optimal plan will be propositional formula. Finally, CDEL takes into account the actions performed in the MAS. Thus, the optimal plan written in CDEL includes actions performed by agent. Precise definition of CDEL is presented in van der Hoek and Wooldridge work [7].

5 Example of Coalition Formation Experience

In this section, an example of usage of the previously mentioned mathematical representation of a coalition is presented. Consider the following application, where business application encompasses several processes. Each process is performed by an agent. Each process is triggered by some state of the system and results in another state. A process is represented by an action. Triggering a state is the precondition of the action. Consider a situation, where four agents can perform 10 actions with the following precondition and resulting propositions.

Agent	Action	Precondition	Resulting proposition
A_1	α_1	p_1	p_2
A_2	α_2	p_1	p_3
A_1	α_3	p_2	p_4
A_3	α_4	p_3	p_4
A_3	α_5	p_3	p_5
A_1	α_6	p_4	p_7

A_3	α_7	p_5	p_7
A_1	α_8	p_5	p_6
A_3	α_9	p_3	p_9
A_4	α_{10}	p_9	p_8

The objective of a coalition formation algorithm is to find an optimal plan for the previously defined multi-agent system, which guides the system from proposition p_1 to proposition p_8. The experience will be written in the following experience pair:

$$\left\{\left\langle\left\langle A_1, A_2, A_3, A_4\right\rangle\right\rangle[?\, p_1]p_8 \bigcup \left\langle\left\langle A_2, A_3, A_4\right\rangle\right\rangle[?\, p_1; \alpha_2; \alpha_9; \alpha_{10}]p_8\right\}. \quad (4)$$

6 Experience Ontology

In this chapter, an ontology for the coalition formation experience is presented which encompasses several ontological layers. This ontology is modeled in the ontology web language (OWL Lite) using Protégé ontology tool. Screenshots of the ontology are made by the Jambalaya plug-in for Protégé. This ontology can be a part of the whole ontology for an experience management subsystem [14].

6.1 Layered Ontology for Coalition Formation Experience

In the following figure (**Figure 1**), an ontological tree is presented, which include classes and generalization relation between them. Each class represents one concept which, in turn, represents a set of objects which have similar properties and purpose. This definition allows to create concepts which have the same properties, but different purposes. The ontological tree has a root named *owl:Thing*. This concept is the general class of all classes in any OWL ontology. Each class name in ontology has a prefix name which determines the ontology layer; e.g., *gco* prefix means that class is from general coalition ontology layer which is the main layer of experience ontology. *clpc* prefix delegates an ontological layer which is modeling coalition logic for propositional control. The layer intended for concurrent dynamic epistemic logic has the *cdel* prefix. Finally, *atl* is the prefix for alternating-time temporal logic.

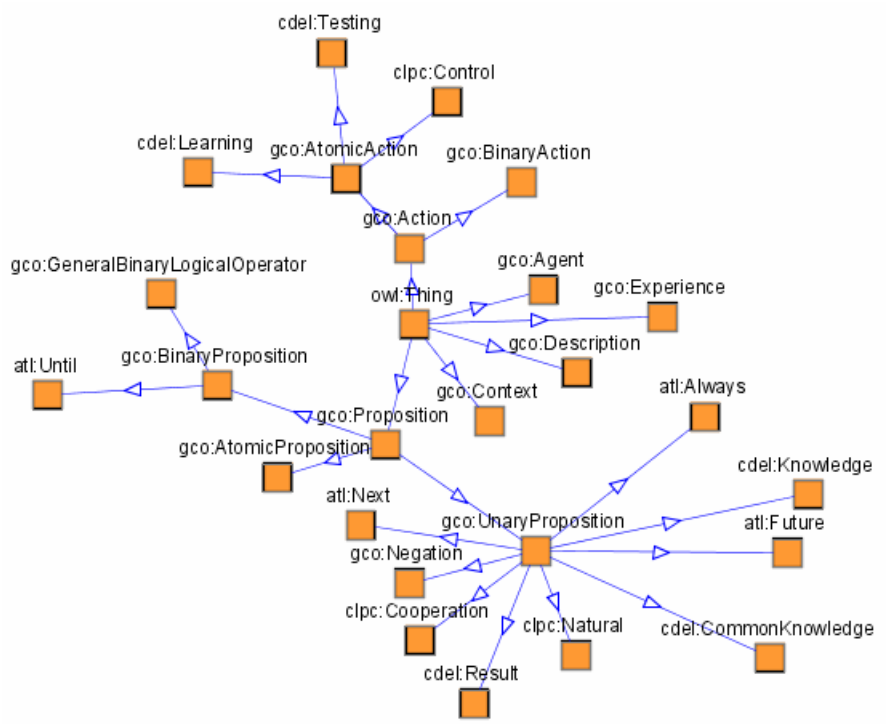

Figure 1
Class hierarchy in layered ontolofy for coalition formation experience

6.1.1 General Coalition Ontology – the Main Ontological Layer

The *Experience* concept is the central part of the whole layered ontology, which defines the experience item. In the coalition formation process, the experience item is divided into two parts which have similar structure, but different meaning. The first part defines a problem, which is solved by the solution stored in the second part of the solution. Both parts include the following two concepts: *Context* and *Action.* In the problem part, *Context* stands for context in which the problem will be solved, while *Action* defines objectives of the problem. Nevertheless, in the solution part, the *Context* concept refers to a coalition which solves the problem using a plan defined in the *Action* concept. The *Action* concept describes all actions which can be executed by an *Agent* in a multi-agent system. Another very important concept is *Proposition*, which refers to a mental state of the coalition.

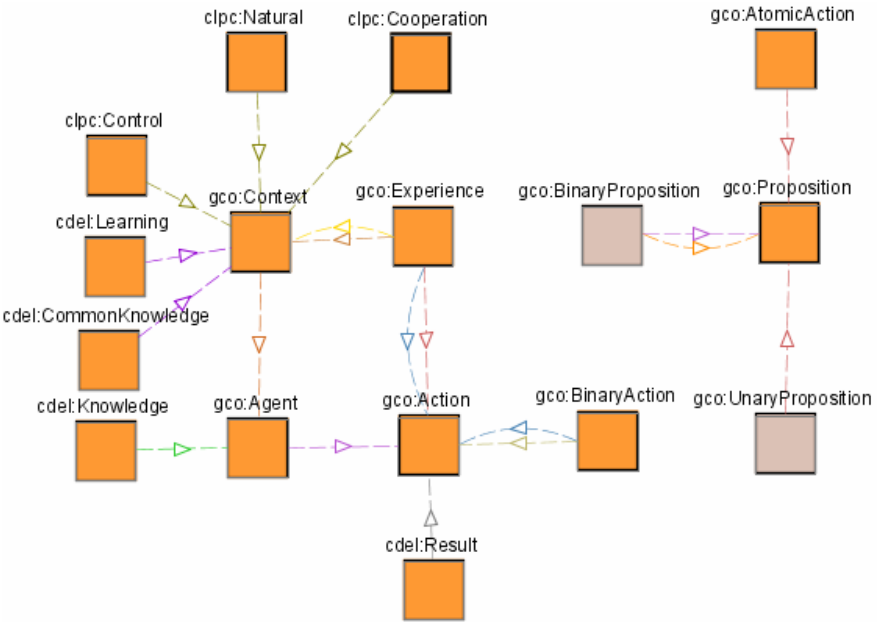

Figure 2
Various relations between concepts in ontological tree

6.1.2 Subontologies of the Layered Ontology for the Coalition Formation Process

In the previous subsection, description of the main ontological layer was proposed. In this section, other layers are presented. Each layer should exploit the more general ontology. The main layer is the parent for all ontologies in the layered ontology. Each logical extension results in one layer which creates more specific ontology.

This specialization concentrates on the *Action* and *Proposition* concepts. It is obvious that specialization depends on the type of the logic. If the logic is able to describe actions, then specialization of the *Action* concept is essential. If the logic is able to describe mental state of the system, then specialization of *Proposition* concepts is also fundamental. For example, consider that a coalition plan is described by alternating-time temporal logic which is capable to describe dynamics only within the systems modeled by an alternating-time system [1]. Without this description this logic can describe only mental state of the system without dynamics, because there is no direct relation between the action part of ontology and the propositional part of ATL subontology. On the other hand, concurrent dynamic epistemic logic describes a dynamics in concurrent system

using propositions and actions. In **Figure 2**, the relation between proposition concept in CDEL subontology and action part of the ontology is obvious.

Conclusions

In this paper, we introduce the coalition formation problem from the experience point of view. Introduction into the experience management is also proposed. Coalition is represented in the knowledge system as Bergmann's experience pair which encompasses problem and solution. Both parts have similar structure with slightly different meaning. The problem includes context and objective parts. The solution encompasses external and internal representation of the coalition.

This work concentrates on the representational part of experience management cycle [13]. In the future, we will concentrate on similarity measurement between cases and on its experience adaptation which is one of the crucial parts of the experience management system. The similarity measurement allows comparing two pieces of learned experience. Adaptation of the experience is essential in the reuse of experience, where learnt experience is adapted for new problem.

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References

[1] Alur R., Henzinger T.A., Kupferman O: Alternating-Time Temporal Logic, *Compositionality -- The Significant Difference,* LNCS 1536, Springer-Verlag, pp. 23-60, 1999

[2] C. Bartolini, C. Preist, M. R. Jennings: A Software Framework for Automated Negotiation, (Edited by R. Choren and *et al*), Lecture Notes in Computer Science 3390, Springer-Verlag, Berlin, Heidelberg, pp. 213-235

[3] V. Dung Dang, N. R. Jennings: Generating coalition structures with finite bound from the optimal guarantees, In Proceedings of 3rd International Conference on Autonomous Agents and Multi-Agent Systems, New York, USA, pp. 564-571, 2004

[4] Dang T.-Tung, Frankovič B., Budinská I.: Optimal Creation of Agent Coalitions for Manufacturing and Control, Computing and Informatics, Slovak Academic Press Ltd., Vol. 22, No. 1, 2003

[5] V. Dung Dang, N. R. Jennings: Coalition Structure Generation in Task-Based Settings, In Proceedings of 17th European Conference on AI, Trento, Italy, pp. 210-214, 2006

[6] van Ditmarsch H. P., van der Hoek W., Kooi B. P.: Concurrent Dynamic Epistemic Logic, Technical Report OUCS-2003-01, Department of Computer Science, University of Otago, 2003

[7] van der Hoek W., Wooldridge M.: Cooperation, Knowledge, and Time: Alternating-time Temporal Epistemic Logic and its Applications. In Studia Logica, 75(1):125-157, October 2003

[8] V. Oravec, B. Frankovic: Coalition Formation for Large Scale Multi-Agent Sytems, 12th IFAC Symposium on Information Control Problems in Manufacturing, IN PRESS

[9] Sandholm, T., Larson, K., Andersson, M., Shehory, O., Tohmé, F.: Coalition Structure Generation with Worst Case Guarantees. Artificial Intelligence, 111(1-2), pp. 209-238, 1999

[10] Tamma V., Phelps S., Dickinson I. Wooldridge M.: Ontologies for Supporting Negotiation in E-commerce, Engineering Applications of Artificial Intelligence, 18(2), pp. 223-236, March 2005

[11] van der Hoek W., Wooldridge M.: On the logic of cooperation and propositional control, Artificial Intelligence, No. 64, pp. 81-119, 2005

[12] Shehory O, Kraus S.: Feasible Formation of Coalitions Among Autonomous Agents in Non-Super-Additive Environments, Computational Intelligence, Vol. 15, No. 3, 1999

[13] Bergmann R.: Experiencemanagement, Springer, 2002, ISBN 3-540-44191-3

[14] Budinska I., Frankovič B.: Central Ontology Layer for Power Grid Scheduling, In Proceedings of IEEE International Conference on Mechatronics, Budapest, 2006, pp. 267-271, ISBN 1-4244-9713-4