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A FIPA-ACL Ontology in Enhancing Interoperability Multi-Agent Communication

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Abstract. The nature of computing paradigm has shifted from centralized, static and closed to distributed, dynamic and open due to the advent and popularity of Internet. Multi-agent system (MAS) gained popularity due to its characteristic that match with the paradigm shift. In order for MAS to interact efficiently and communicate meaningfully, agent communication language (ACL) plays an important role. FIPA-ACL is an ACL developed by FIPA that has become the de facto of ACL implementation in MAS. Another emerging trend due to Internet is the Semantic Web (SW). Semantic web is an extension of current World Wide Web which encodes the content of the web with well-defined meaning to allow it to be processed by machines such as computer (agents). Hence, combining the existing FIPA-ACL with semantic web can bring the ACLs to another level to enhance the interoperability in MAS. In this paper, a FIPA-ACL ontology in OWL is developed to enhance the communication between agents in MAS.

Keywords: Agent Communication Language, FIPA-ACL, Semantic Web, Ontology, OWL

1 Introduction

Internet has changed the computational interaction in today's computing environment. The computing paradigm shifted from centralized, closed, static to distributed, open and dynamic. This computing paradigm shift is also referred to as open system [1, 2]. Agent technology which emerged as a new software computing paradigm matches the

[1] Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

open system [3,4]. Multi-agent system is made of multiple heterogeneous agents that may be distributed in different environments and enter and leave freely in the agent community [5]. As a result, agents need to interact or communicate in order to achieve some goals or tasks [6]. For agents to carry out interaction such as coordination, cooperation, collaboration and negotiation require, they need to communicate in a manner that can be understood by each agent [7,8,9,10]. Agent communication language (ACL) [11] is the communication language used to achieve interoperability between agents. . Two of the most common ACLs adopted by the MAS are KQML and FIPA-ACL. KQML is the first ACL developed by DARPA knowledge sharing effort [12]. The high level communication was initially developed to exchange information and knowledge for knowledge based system and it was then extended for communication between agents. FIPA-ACL was developed by FIPA which is a non-profit organization established to promote agent technology and interoperability between agent applications [13,14]. FIPA-ACL is adopted more widely than KQML in recent years due to the formal semantic of FIPA-ACL and affordance of FIPA in promoting agent technology through as set of specification that acts as guideline for developers and industry vendors.

Another emerging trends in Internet systems is the semantic web. Semantic web is the extension of the current web by encoding the web content resources with well-defined meaning that allow it to be machine process able [15]. In order to realize the semantic web, a set of technologies such as RDF [16], RDFS [17], and OWL [18] have been created. Besides, other technologies such as SWRL [19] and SPIN [20] were created to incorporate rules into semantic web to express constraints, rules and business logic. There is an increasing trend of applying semantic web into MAS to increase computational efficiency and to communicate meaningfully. Moreover, SW is used as ontology, knowledge base, validity constraints, consistency checking among others. SW has also been used in ACL as encoding for communication. In this paper, a FIPA-ACL ontology is developed to act as standardized ontology for MAS to adopt and extend it as an ACL component in MAS to enhance the interoperability of communication between MAS.

This paper aims to introduce a FIPA-ACL ontology that can be reused and imported by agents' applications that communicate using FIPA-ACL. The ontology is created through steps ontology development process. . The remainder of this paper is organized as follow. Section 2 describes some of the related work in FIPA-ACL ontology. The ontology engineering methodology is described in Section 3. Section 4 describes the series of steps in FIPA-ACL ontology development and finally, Section 5 concludes and summarizes the work presented in this paper.

2 Related Work

In this section, some of the related works in ontology-based FIPA-ACL are reviewed to serve as the foundation and motivation of this research. This review is organized in chronological order to observe how the researches in this area have progressed. One of the earlier works observed is by FIPA on its specification to encode the content of the message in RDF encoding known as the FIPA RDF Content Language

Specification [21]. This specification specifies how to represent objects, propositions and actions in RDF and in different RDF version with different extensions. The motivation for encoding in RDF is to increase the level of interoperability. The advantages of RDF encoding include extensibility, reusability, simplicity and standards for data and schemas exchange. However, RDF is just a data format for encoding and exchange, and as a result the expressiveness of RDF is limited.

Another semantic web technology DAML has also been proposed to encode the ACL message [22]. The richer expressivity of DAML compared to RDF and RDFS enriched the content expressed in the ACL message. In this work, a DAML ontology is defined for the communication. A demo application of ITTalks project was used to illustrate the communication encoding in DAML. Unfortunately, DAML as a cornerstone of OWL did not gain its momentum as semantic web technologies..

Zou continued his research effort in ACL using semantic web language as content language but this time he focused on OWL. Travel Agent Game in Agentcities (TAGA) is a FIPA-compliant framework that extended and enhanced Trading Agent Competition (TAC) scenario in Agentcities as an open MAS environment. OWL was used as the content language in FIPA-ACL messages for agents to communicate with each other and reasoning about the action and services. By utilizing the benefits of OWL, the content of messages can be more expressive, unambiguous, computer-interpretable, interoperable, has automated reasoning techniques, higher-level of interoperability between agents and meaningful content can be shared [23,24].

AgentOWL is another research that incorporated OWL as representation for agent internal model and communication [25]. It is a MAS distributed framework that built on top of JADE with a generic knowledge model for agent. Formal description of the model is represented using description logic. There are five main elements in the model including resources, actions, actors, context and events. AgentOWL used Jena semantic reasoner to reason the context, resource, action and knowledge domain of the agent and content of agent communication. CommonKADs is used to model and developed the MAS, the UML and AUML modeling language is used for modeling formalism. As a result, the agent knowledge model is more generic and expressive and can easily adopted and used in other similar applications.

Pu used semantic web representation for negotiation protocol in electronic commerce [26]. Ontology is used to describe the negotiation protocol to increase the efficiency of the negotiation process. The negotiation protocol used in this research is the contract net protocol. The prototype demo was built on top of JADE and the reasoning used Jena API. This work was further extended using OWL for the agent communication process in a layered architecture.

Semantic agent model (SAM) used semantic web technologies in MAS modeling and knowledge base support [27]. In SAM, semantic web rule language (SWRL) is used in modeling the behaviour and constraints of different agents. A three layered architecture is used to model the agents which is made up of a knowledge base layer, an engine layer and a low level action layer. The different states of agent actions are modelled using extended FSM concept.

Fornara has been the one of the important key players in representing ACL social semantic model using obligation and norms [28,29]. An obligation ontology is developed to model the obligation between debtor and creditor in temporal proposition. An external program is used to keep track of the temporal constraints in the temporal proposition to determine the different states of the obligations. Fornara and her team has further the research into the representation of policy and artificial institution [30,31].

It can be observed that there are some ongoing works in ACLs. However, the complete ontology for FIPA-ACL has not been developed yet. Hence, the objective of this research is to develop an FIPA-ACL ontology for communication interoperability between agents.

3 Methodologies

To develop the FIPA-ACL ontology, we used the ontology engineering approach. The ontology development process used in this work is from the Noy and Deborah ontology engineering approach [32] which was also adopted by many of the researchers working on ontology development

This ontology development process includes several steps that require iteration process for refinement and evaluation. The steps in this ontology development approach are as follow:

1. Determine the domain and scope of the ontology.
2. Consider reusing the existing ontologies.
3. Enumerate important terms in ontology.
4. Define the classes and class hierarchy.
5. Define the properties of classes.
6. Define the facets of slots.
7. Create instances.

The first step in the development of the ontology is defining the domain and scope of the ontology. This is done by going through a list of question which consist of basic question and competency questions. By going through this list of question, the domain and scope of the ontology can be roughly identified. The next step to consider is to consider reusing existing ontologies by checking whether there are any existing ontologies that have been developed that are suitable to be reused or extended. Reusing any existing well known ontologies can increase the interoperability of the developed ontology. The next step is to identify a list of important terms that are related to the ontology domain. This list of terms can be identified from numerous related documents or from domain experst. Normally, nouns identified will be the class of the ontology and verbs will be the relationship of the connected classes in the ontology. The list of terms will lay the foundation for defining the classes and class hierarchy in the next step. There are several approaches in developing the class hierarchy such as the top-down development approach, bottom-up development approach and the hybrid approach. The top-down development approach is based on the most general concept and is narrowed down to specialized concept. On the other hand, the bottom-up development approach is based on the most specific concept and grouping related specific concept to form general class. The hybrid approach combines the two processed and meet in the middle. After defining the classes and its hierarchy, the next step is to define the properties that are related to these classes. This properties are to define the attributes values of the particular class. The relationship to relate the individual between classes is also defined in this step. In the subsequent step, the facets of the identified properties values is defined. These facets values include the cardinality, value-type, domain and range. The final step is to populate instances and individuals into the ontology. These steps need to be done in several iteration before the final ontology is developed and completed.

4 FIPA-ACL Ontology Development

4.1 Determine the domain and scope of the ontology

The domain ontology will cover the FIPA-ACL specification which includes the different communication acts, the different interaction protocols, content language and the message structure. The ontology will be used by agents (autonomous entity) that exchange information and knowledge conforming to FIPA-compliances (agents are communicating using FIPA-ACL). The ontology will identify the terms and vocabulary used for FIPA-ACL conversation message exchanges and to infer the performative that is used in the message. The ontology can then be imported by other agents that use FIPA-ACL as communication language and it can also be further extended by those that want to introduce extra performatives besides the basic set of performatives to enhance the interoperability between agent communication. Furthermore, the ontology might able to answer the following competency questions. Which performative should be used for the next message based on the content and performative of the previous message? Before performing the selected performative, a validation is carried out by verifying whether the agent knows about the content or is the agent able to carry out the actions by referring to the knowledge based.

4.2 Consider reusing the existing ontologies

There are two related ontologies of FIPA-ACL that has been developed by Zou in TAGA and Dickinson in NUIN. These two ontologies will serve as the base reference ontologies for developing the ontology in this paper. In Zou’s ontology, no semantic model is considered in defining the FIPA-ACL ontology. In Dickson’s ontology, only the mentalistic model in the FIPA-ACL ontologies is considered. Another ontology that will be reused in this work is the obligation ontology by Fornara. This obligation ontology is based on the semantic model of social commitment inferred from social interaction.

4.3 Enumerate important terms in the ontology

The list of terms for this ontology is extracted from various documentation including the FIPA specifications, publication in agent communication language, agent communication semantic model, interactions between agents and others. However, the most important document is the set of FIPA-ACL specifications since this is the main guideline for developers to develop FIPA-ACL MAS . Some of these terms include performatives, message, conversation, agent, sender, receiver, content, language, encoding, ontology, conversation-id, reply-with, in-reply-to, and reply-by. The nouns that identify the list of terms would normally be considered as classes and the verbs that identify the list of terms would be the relationships that connect the classes identified.

4.4 Define the classes and the class hierarchy

The hybrid approach is used to define the FIPA-ACL ontology.. The more salient concepts are defined first and then generalization and specialization are applied to these concept appropriately. For examples the performative class is a super class for the different performatives subclass and protocol classes. The list of protocols are shown in Figure 1. Other salient classes identified as part of the ontology are shown in Table 1.

Table 1. FIPA-ACL ontology classes.

Classes	rdf:type	SubClassOf
Agent	owl:Class	owl:Thing
AgentPlatform	owl:Class	owl:Thing
CommunicativeAct	owl:Class	owl:Thing
Conversation	owl:Class	owl:Thing
Message	owl:Class	owl:Thing
Object	owl:Class	owl:Thing
Ontology	owl:Class	owl:Thing
Protocol	owl:Class	owl:Thing
Role	owl:Class	owl:Thing
Rule	owl:Class	owl:Thing
Service	owl:Class	owl:Thing
State	owl:Class	owl:Thing

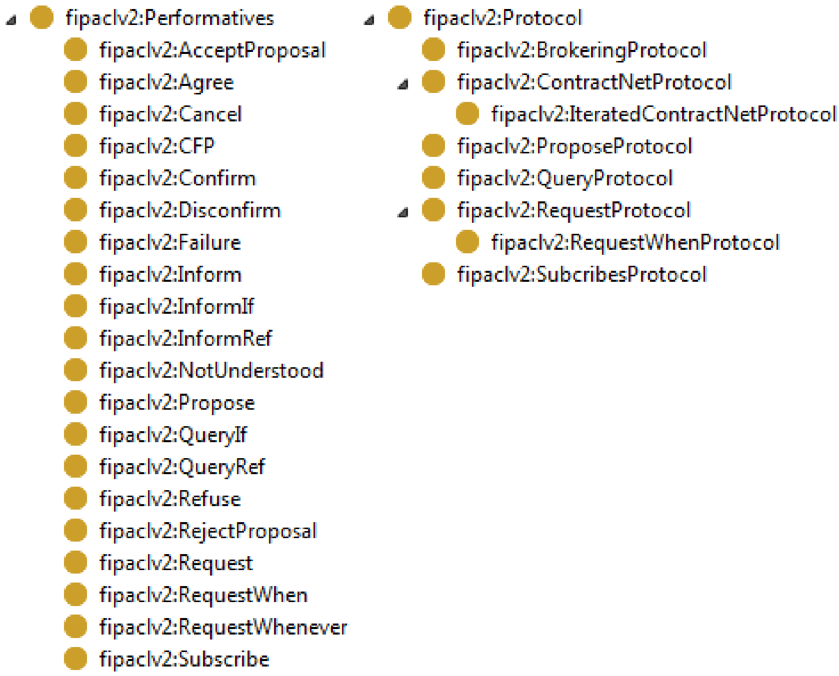

Fig. 1. FIPA-ACL ontology class hierarchies.

4.5 Define the properties of classes-slots

After identifying the class hierarchy, the attributes values of the classes and relationships between classes are identified. The relationships between classes are identified through the list of verbs from the terms identified. The attributes values of the classes are the remaining terms that are both not classes and relationships. The relationships between classes will be identified as the object properties. Whereas the attributes values are identified as data properties. Table 2 shows the some of the object properties identified for the ontology.

Table 2. Object properties with domain and range.

PropertyName	Type	Domain	Range
atPlatform	owl:ObjectProperty	Agent	AgentPlatform
hasAgentAddress	owl:ObjectProperty	Agent	URL
hasContent	owl:ObjectProperty	Message	Fact, Object, Action
Ontology	owl:ObjectProperty	Message	Ontology

hasProtocol	owl:ObjectProperty	Message	Protocol
hasReceiver	owl:ObjectProperty	Message	Agent
hasSender	owl:ObjectProperty	Message	Agent
hasService	owl:ObjectProperty	Agent	Service
inReplyTo	owl:ObjectProperty	Message	Expression
ownership	owl:ObjectProperty	Service	Agent
replyBy	owl:ObjectProperty	Message	Time
replyTo	owl:ObjectProperty	Message	Agent
replyWith	owl:ObjectProperty	Message	Expression

4.6 Define the facets of the attributes

The facets identified include the allowable value type, values, cardinality and other features. The cardinality for the attributes can specify the maximum value, minimum value and the exact value of the attributes. The basic allowable value types would be based on xml schema data types permitted in OWL 2 DL. The value types can also be an instance value of classes defined. If the value type is an instance value then universal and existential quantification, set operators of union and intersection can be used to define the slot facets. The domain and range of the properties is defined to restrict the allowable value for each relationship. Some of the domains and ranges of the relationship property are shown in Table 2.

4.7 Create instances

In this ontology no instances will be populate because the instance of the ontology will be create during the exchange of messages between agents. Some of testing instances are populated to validate the consistency and soundness of the ontologies.

5 Conclusion

This paper aims is to create a more complete FIPA-ACL ontology based on FIPA-ACL specification that is required to facilitate the communication between agents. By combining FIPA-ACL and OWL 2 DL for the FIPA-ACL ontology, it is believed that it can provide additional advantages and overcome some limitations. OWL 2 DL is a decidable subset of first order logic. Hence, using OWL 2 DL as a content language makes the logic of representation decidable compared to modal logic or first order logic. Besides, the rich expressiveness and incremental inferment of new knowledge, OWL 2 DL is able to represent the different types of content for FIPA-ACL including object, action and expression. In the next step, FIPA-ACL ontology will be equipped with the semantic model which allow the communication process to be verified.

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References

1. Luck, M., McBurney, P., Preist, C.: Agent technology: enabling next generation computing (a roadmap for agent based computing). AgentLink. (2003)
2. Artikis, A. 2012.: Dynamic specification of open agent systems. Journal of Logic and Computation 22(6): 1301–1334 (2012)
3. Luck, M., McBurney, P., Shehory, O., Willmott, S.: Agent technology roadmap: Overview and consultation report. AgentLink III. (2004)
4. Luck, M., McBurney, P., Shehory, O., Willmott, S.: Agent technology: computing as interaction (a roadmap for agent based computing). University of Southampton. (2005)
5. Sycara, K. P.: Multiagent systems. AI magazine. 19(2), pp. 79 - 93 (1998)
6. Payne, T. R., Paolucci, M., Singh, R., Sycara, K.: Communicating Agents in Open Multi Agent Systems. In In Proc. of 1 st GSFC/JPL Workshop on Radical Agent Concepts (WRAC) (2002)
7. Beer, M., D'inverno, M., Luck, M., Jennings, N., Preist, C., Schroeder, M.: Negotiation in multi-agent systems. The Knowledge Engineering Review, 14(3), 285-289. (1999)
8. Jennings, N. R.: Commitments and conventions: The foundation of coordination in multi-agent systems. The knowledge engineering review, 8(3), 223-250. (1993)
9. Olfati-Saber, R., Fax, J. A., Murray, R. M.: Consensus and cooperation in networked multi-agent systems. Proceedings of the IEEE, 95(1), 215-233. (2007)
10. Poslad, S.: Specifying protocols for multi-agent systems interaction. ACM Transactions on Autonomous and Adaptive Systems (TAAS), 2(4). (2007)
11. Labrou, Y., Finin, T., Peng, Y.: Agent communication languages: The current landscape. IEEE Intelligent Systems and Their Applications, 14(2), 45-52. (1999)
12. Finin, T., Weber, J., Wiederhold, G., Genesereth, M., Fritzson, R., Mckay, D., Beck, C.: Draft specification of the KQML agent-communication language. (1993)
13. FIPA.: FIPA specification part 2: Agent communication language. Technical report, FIPA-Foundation for Intelligent Physical Agents. (1997)
14. FIPA.: FIPA ACL Message Structure Specification. Foundation for Intelligent Physical Agents. (2002)
15. Berners-Lee, T., Hendler, J., Lassila, O.: The semantic web. Scientific american, 284(5), 28-37. (2001)
16. Cyganiak, R., Wood, D., Lanthaler, M.: RDF 1.1 concepts and abstract syntax. W3C Recommendation. (2014)
17. Brickley, D., Guha, R. V., McBride, B.: RDF Schema 1.1. W3C Recommendation. (2014)
18. Hitzler, P., Krötzsch, M., Parsia, B., Patel-Schneider, P. F., Rudolph, S.: OWL 2 web ontology language primer. W3C Recommendation. (2009)
19. Horrocks, I., Patel-Schneider, P. F., Boley, H., Tabet, S., Grosof, B., Dean, M.: SWRL: A semantic web rule language combining OWL and RuleML. W3C Member submission, (2004)
20. Knublauch, H., Hendler, J. A., Idehen, K.: SPIN-Overview and Motivation. W3C Member Submission. (2011)
21. FIPA.: RDF Content Language Specification. FIPA-Foundation for Intelligent Physical Agents. (2000)

22.Zou, Y., Finin, T., Peng, Y., Joshi, A., Cost, S.: Agent Communication in DAML World”. In Innovative Concepts for Agent-Based Systems: First International Workshop on Radical Agent Concepts, WRAC 2003. Springer. (2003)
23.Zou, Y., Finin, T., Ding, L., Chen, H. (2003). TAGA: Using Semantic Web Technologies in Multi-Agent Systems. In International Joint Conference on Artificial Intelligence 2003. (2003).
24.Zou, Y., Finin, T., Ding, L., Chen, H., Pan, R.: Using Semantic web technology in Multi-Agent systems: a case study in the TAGA Trading agent environment. In Proceedings of the 5th international conference on Electronic commerce. pp. 95-101. ACM. (2003)
25.Laclavik, M., Balogh, Z., Babik, M., Hluchý, L.: AgentOWL: Semantic knowledge model and agent architecture. Computing and Informatics, 25(5), 421-439. (2012)
26.Pu, Q., Fu, S., Cao, Y., Hou, Z.: Adopting Ontology and agent in electronic negotiation service. In 8th IEEE International Conference on Cognitive Informatics ICCI'09. pp. 547-551. IEEE. (2009)
27.Subercaze, J., Maret, P.: SAM: Semantic Agent Model for SWRL rule-based agents. In International Conference on Agents and Artificial Intelligence, Vol. 2, pp. 244-248 (2010)
28.Fornara, N., Colombetti, M.: Ontology and time evolution of obligations and prohibitions using semantic web technology. In International Workshop on Declarative Agent Languages and Technologies. pp. 101-118. Springer, Berlin, Heidelberg. (2009)
29.Fornara, N., Colombetti, M.: Representation and monitoring of commitments and norms using OWL. AI communications, 23(4), pp. 341-356. (2010)
30.Fornara, N., Okouya, D., Colombetti, M.: Using OWL 2 DL for expressing ACL Content and Semantics. In European workshop on multi-agent systems. pp. 97-113. Springer, Berlin, Heidelberg. (2011)
31.Fornara, N., Cardoso, H. L., Noriega, P., Oliveira, E., Tampitsikas, C., Schumacher, M. I.: Modelling agent institutions. In Agreement technologies. pp. 277-307. Springer Netherlands. (2013)
32.Noy, N. F., McGuinness, D. L.: Ontology development 101: A guide to creating your first ontology. Knowldege systems laboratory, stanford university. Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880. (2001)