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A Commentary on Standardization in the Semantic Web, Common Logic and MultiAgent Systems

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Abstract. Given the ubiquity of the Web, the Semantic Web (SW) offers MultiAgent Systems (MAS) a most wide-ranging platform by which they could intercommunicate. It can be argued however that MAS require levels of logic that the current Semantic Web has yet to provide. As ISO Common Logic (CL) ISO/IEC IS 24707:2007 provides a first-order logic capability for MAS in an interoperable way, it seems natural to investigate how CL may itself integrate with the SW thus providing a more expressive means by which MAS can interoperate effectively across the SW. A commentary is accordingly presented on how this may be achieved. Whilst it notes that certain limitations remain to be addressed, the commentary proposes that standardising the SW with CL provides the vehicle by which MAS can achieve their potential.

1 Introduction

Since Tim Berners-Lee [1] publicly stated his vision of the Semantic Web (SW), there has been much work on devising Web technologies for explicitly annotating the existing data on the Web and for performing intelligent reasoning upon it. One potentially powerful area worthy of investigation is a SW in which software agents will be able to perform tasks and take decisions on behalf of humans. Given the ubiquity of the Web itself and developments in MultiAgent Systems (MAS) [34], the SW offers a global platform that MAS could be brought to bear and allow software agents to intercommunicate across this most wide-ranging arena.

2 Common Logic

The SW includes languages for ontologies and reasoning such as Resource Description Framework (RDF, www.w3.org/RDF), Web Ontology Language (OWL, www.w3.org/TR/owl-features), and TRIPLE (triple.semanticweb.org) [18, 2].

Common Logic (CL) arose from two separate projects that were aimed at developing parallel ANSI standards for conceptual graphs and the Knowledge Interchange Format (KIF) [11]. These two projects eventually merged into a single

ISO project, in order to develop a common abstract syntax for a family of logic-based languages. In fact, CL is now an established International Standard that provides a logic framework for the exchange of data and information amongst distinct computers on an open communication network. ISO/IEC 24707:2007 [19] is the International Standard that describes a selection of logic languages that are directed towards this aim. This international standard ensures that the logic languages that it specifies all share their declarative semantics. Also, every logic language in the CL must be compliant with the generation of first-order logical sentences. All of this must be centred on sharing of data and information between incongruous computer systems. Hayes and Menzel [16] defined a very general model theory for CL, which Hayes and McBride [15] used to define the semantics for the languages Resource Description Framework (RDF) and Web Ontology Language (OWL). In fact, CL is not a single language that specifies a unique set of syntactic forms and hence it does not exclude any other forms of languages. CL allows for a number of so-called dialects to interoperate with the CL common abstract syntax. These dialects can have their own syntax, but must share uniform semantics, so that they can then be expressed using the CL abstract syntax.

Three concrete syntaxes are specified in the standard:

- CGIF - Conceptual Graph Interchange Format which is a text version of conceptual graphs.
- CLIF - Common Logic Interchange Format whose syntax is based on KIF.
- XCL - XML-based notation for Common Logic. This is intended to be a generic dialect for distributing CL content on any network that supports XML [19].

As stated by Sowa[31], CL can also be utilized to map to and from controlled natural languages such as using CLCE (Common Logic Controlled English).

3 CL, Ontologies and the SW

An ever-increasing number of applications are benefiting from the use of ontologies as a way to achieve semantic interoperability among heterogeneous, distributed systems [32]. However, different interpretations may occur across different ontologies that lead to mismatches being made by MAS if they are to interoperate across them. One way forward would be to map the ontologies as suggested by Ding et al. [8]. However, this would result in the numerous combinations of mappings between each of the different ontologies.

A more effective approach would be to map each ontology with CL, as it covers a larger set of first-order logic. As such it provides a general basis for dialects, applications or even networks to determine/establish conformance to CL syntax, hence a basis for meaning-preserving translation [24]. It also makes CLIF a genuine network logic, because CLIF texts retain their full meaning when transported across a network, archived, or freely combined with other CLIF texts (unlike the SW's OWL-DL and GOFOL) [17]. The challenge arises when not all of the knowledge available in the ontology can be transferred back into CL as first-order logic and therefore this would filter out and reduce some of the information that can be transferred on to other mapped ontologies. The significance of this will depend on the importance of the non-transferable knowledge. It may also be possible to retain this knowledge as, say, comments; it would also explicate these differences and focus research energy onto how they may be in turn be interoperated. Success in this approach has been demonstrated with interoperating ontologies in the Amine conceptual graphs-based software (amine-platform.sourceforge.net) with the SW's Protégé OWL (Web Ontology Language) software (protege.stanford.edu) [27].

4 MAS Interoperability

Central to the development of the SW is the concept of machine-readable transfers of information, marking a distinct move away from the current Web that was, as pointed out by MciLraith et al [23] 'designed primarily for human interpretation and use'. We can of course note that Web Services are designed to provide interoperability between proprietary IT solutions, and have successfully contributed to the growth of electronic business and e-commerce solutions. However, MAS are designed to exist in a far more dynamic way. They need to develop their own interconnections and exist as self regulating open and decentralized applications. In this way, they would avoid the problems of traditional systems including 'software reuse and discovery' [28] while supporting interoperability by implementing semantic structure in a rigorous and standardized way. Fensel et al [9] state that the implementation of Web Services in an interoperable and machine-to-machine understandable manner would have a further impact on e-commerce and enterprise applications integrations. They identify this development as 'a significant, if not the most important, factor in IT'. Web Services are being seen as the technological platform to deliver services to requesters. Agents on the other hand are intelligent systems that are trying to reason within the world they know. They can offer services but also make use of services provided elsewhere in order to reach their goals. Furthermore they could assemble, or 'orchestrate', a series of Web Services on the fly according to their autonomously decided aims at the time. An agent, for example, may assemble individual Web Services into the requisite business processes so that it can successfully negotiate a high-level business deal or transaction. Presently the orchestration (business or otherwise) remains a human endeavour [33].

Meanwhile Leuf [21] draws attention to the fact that even 'the lack of formal compatibility on syntactic as well as semantic levels greatly hinders the ability to accommodate domain interoperability' [21]. Although the ability to rigorously share ontologies is key to 'seamless integration' [20], 'fully automatic derivation of mappings is considered impossible as yet' [5]. In the MAS environment, agents often may not be able to execute their programs properly as expected due to such compatibility issues. Correct interpretation of messages between different agents is essential for successful intercommunication between MAS environments. Goldman et al [12] recommends that 'multi-agent systems can be made more robust if they can autonomously overcome problems of miscoordination'. The same viewpoint is emphasized by Leuf [21], who stresses that 'a major goal is to enable agent-based systems to interoperate with a high degree of autonomy, flexibility, and agility - without misunderstanding.' As a result, this gives rise to the need for a more effective representation to describe and reason over the agent's knowledge domain. As noted by Delugach [6] CL is the first standardized effort at developing techniques for interoperability between systems using various representations. Similarly, CL is supported by various existing commercial and open source software tools that can build and deploy ontologies. Such tools were designed to build ontologies compliant with the industry standards prior to the final CL standard [7].

Also, Flores-Mendez [10] describe the work of standards in MAS. The Foundation for Intelligent Physical Agents (FIPA) have developed a series of MAS specifications like Agent Management and Agent Communication Language. FIPA targets to use a minimal framework to manage agents in an open environment. The Object Management Group (OMG) have proposed a model for agent technologies for the collaboration of agent components and agencies using interaction policies. These agencies are then in turn capable to support agent mobility, security and concurrent execution. The Knowledgeable Agent-oriented System (KAoS) approach addresses the standardization of open distributed architecture for software agents to facilitate agent implementations and messaging communication. Bearing commercial background, General Magic focuses on mobile agent technology in e-commerce allowing agents to move, connect, approve and interact in particular instances. Regardless of all these contributions, Flores-Mendez is of the view that practically not much effort has been realized in establishing a standard and acceptable definition of MAS architectures and frameworks. He states that this is possibly due to the belief that both the architectures and frameworks are required to match individual project requirements for the benefits of project efficiency. To allow for forward development of the SW with MAS, there should thus be stronger support for the integration and interoperability of MAS in this direction.

There are also other critical technical issues in enabling software agents to deal with ontologies, such as the ability to achieve a seamless integration with existing Web browsers or user interface tools. To get around these problems, Blois et al [4] has recommended the SemantiCore framework. Another issue highlighted was that agents in MAS execute in a container separated from the containers of other MAS applications. Whilst work is in place to overcome this, such as Jade - a framework implemented in JAVA for MAS in providing JAVA classes for ontology manipulation), Blois et al [4] would still comment that no agents are specifically designed in support of the deployment of MAS to the SW. Like other agent technology developments, the Semantics MAS development also identifies security issues are remain to be resolved. This arises because security aspects are not taken into active consideration during the development cycle. As a result, security vulnerabilities are often exploited or detected only in the stage of program execution. The FAME Agent-oriented Modelling Language meta-model suggested by Beydoun et al [3], and other previously defined security-aware meta-models, help developers to take a conceptual approach to tackle security requirements of MAS as early as need be during the design stage of the development process. Another advantage would be the introduction of a common identification and validation process to register Agents and accord access rights, and the development and adoption of the WS-I standards in this area (www.ws-i.org).

Nonetheless first order logic based knowledge representation represents a powerful tool for machine-machine interaction. Claimed by Grimm et al [13] as 'the prevalent and single most important knowledge representation formalism.... First-order logic captures some of the essence of human reasoning by providing a notion of logical consequence'. A computer agent is able to deduce and infer data from knowledge statements provided in a logical structure, replicating at least in part human domain expertise. Furthermore, by providing an abstract syntax CL removes the syntactic limitations of traditional first order logic, thus consistently facilitating translation between one language and another as we have stated. Using CL or one of its dialects as a content language will help facilitate the communication between the different agents in the system. CL dialects have been appropriately set up for the purpose of sharing semantics rather than syntax. As raised by Blois et al [4], a compatible or well-suited infrastructure is mandatory for the forward development of semantic MAS. An in all therefore, CL offers a most promising vehicle to MAS interoperability.

5 Preciseness

Given the overall usefulness of CL for MAS on the SW as discussed so far, we can now consider the preciseness of logic in achieving this aim. Sheth et al [29] among others subcategorize types of semantics into distinguishable categories based on how they are constructed and represented. They argue that formal semantics (information or knowledge represented in a highly structured way and in which structures can be combined to represent the meanings of other complex structures), and which would also apply to CL, has had a disproportionately high level of attention even within the SW. Focus is also required on what they view as the two other kinds; implicit semantics (semantics that rely on the analysis of unstructured texts with a loosely defined and less formal structure) and powerful semantics (the representation of imprecise, uncertain, partially true and/or approximate information). In essence, while CL provides a robust level of functionality for MAS interoperability it may, for a significant subtypes of data, not offer sufficient functionality for intelligent machine interaction to replace human domain expertise. Some domain knowledge possessed by human experts is intrinsically complex and may require the more expressive representations of powerful semantics that seeks to allow the representation of degree of membership and degree of certainty. Sheth et al [29]:

'In our opinion, for this vision [the SW] to become a reality, it will be necessary to go beyond RDFS and OWL, and work towards standardized formalisms that support powerful semantics.'

Given that fully functional MAS must be able to process information that is not "precisely axiomatised", subject to degrees or relation and degrees of accuracy then it must be concluded that CL alone is insufficient to fully realize the vision for the SW. There are still as yet "unidentified issues" to be discussed [6]. Notwithstanding a suitable model for "soft computing" that may embody known and unknown issues, the current situation still offers a robust way forward for MAS to interoperate. If that can be achieved without excluding future developments in these relevant fields then the vision of truly interoperable MAS on the SW can still continue to be realized.

6 Further Considerations

We can also note other aspects of CL, such as that it 'also supports some features of higher order logics, such as quantifying over predicates specified in the domain of discourse' [26]. This is highlighted by CL partial support the higher-order logics of Semantics of Business Vocabulary and Rules (SBVR). Section 10.2 of the SBVR specification 'gives a partial mapping of SBVR concepts to OWL and to ISO Common Logic' [22]. In some cases, the mapping is one-to-one, but in many others, a single SBVR concept is represented as a composition of multiple OWL or CL Constructs [22].

Another dimension in the area of specialized digital libraries, where significant improvement has been made over the quality of the information as represented by the SW technologies versus the resources as retrieved by normal search engines [25]. This work also concluded that the SW can leverage the common data model and syntax to ensure the interoperability of resources which is also platform-independent. As a result there are added benefits for MAS to be had in the exchange and collaboration of digital libraries and corporate information repositories across the SW, and on which CL can be brought to bear.

Lastly, no discussion on standardization is complete without reference to approaches that allow unstructured data to be accommodated, hence reducing the need for standards and recognising the Web is built upon myriad formats with various (lack of) structures each serving some individual, ill-compatible purpose. Embedding learning capabilities (e.g. Neural Net) technology that allow intelligent systems to learn like humans from their divergent surroundings provide another approach. Commercial companies like Autonomy (www.autonomy.com) employ such approaches that allows organisations to extract value from the myriad of different systems and information formats within their systems. Autonomy's mixture of propriety Bayesian probability and Shannon theory, allows it to make some 'sense' of the information held in many different formats including voice, video and images. There are also open-source developments such as Unstructured Information Management applications (UIMA, incubator.apache.org/uima). Whilst we can envisage that unstructured data will be an ongoing feature of the Web, the thrust of the SW augmented with CL for the benefit of MAS remains. Rather we can expect the two approaches (structured and unstructured) to be complimentary activities that can benefit from each other. Structuring and thus automating knowledge allows humans to articulate their thinking, capture and interact with it through the productivity of computers i.e. conceptual structures, identified in the "Knowledge Architectures" theme of ICCS 2007 (www.iccs2007.info). Given also that conceptual structures in the form of conceptual graphs are core to CL, the need for CL on the SW for MAS remains undiminished.

7 Concluding Remarks

Even though relatively new as a standard, CL will aid towards achieving the much needed interoperability between the multitude of existing knowledge representations. Assisted by CL, intercommunication between MAS in on the global, most wide-ranging arena that the SW offers will be a key step in leading to the original vision as proposed by Tim Berners-Lee that the SW will evolve human knowledge [1]. Our work has helped identify the need, the key issues and direction in helping to realise that vision. Given the evidence and discussion that we have provided, we would support the view that additionally standardising the SW with CL provides the vehicle by which MAS can achieve their potential.

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