Ontologies and Complex Command and Control Decision-making Behavior Modeling:

AAAI-99 Ontology Management Workshop Position Paper

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1. Introduction

This brief position paper discusses some of the workshop's goals and related questions from a perspective founded on projects MITRE has been leading. These projects enable ontology-based decision-making behavior for US Department of Defense systems and simulations, ranging from the individual combatant level to higher echelon command and control (C2). Our projects have used both ISI/USC's Loom description logic system and Cycorps' CYC knowledge system, the standard knowledge representation languages of Ontolingua, Knowledge Interface Format (KIF), and Open Knowledge Base Connectivity (OKBC), and a variant of the agent communication language KQML. Our current project is closely aligned with the goals and some of the participants of the DARPA High Performance Knowledge Base (HPKB) program, and both addresses aspects of and uses ontologies developed for, the course of action (COA) challenge problem. In addition, we are extending these existing ontologies and developing others that are appropriate to collaborative multi-agent command and control decision-making at the battalion and regiment levels.

2. Standardization

We consider standardization to be essential, extending even to the definition of the term "ontology". Standardized ontologies promise to eventually reverse the "tower of Babel" of non-interoperablity in which the computing world in general resides. One common language is essential to that task. Non-standard ontologies can co-exist alongside the standard ontology. With the standard ontology acting as an interlingua, the non-standard ontology's terms would need to be grounded in the terms of the interlingua. The terms of the interlingua would be employed as the denotational semantics for all the non-standard terms.

The US armed services, including our sponsors, are currently investing billions of dollars in a program which is in part designed to achieve simulation interoperablity through standardized object-oriented schema. This program is known as the Joint Simulation System (JSIMS), and one of its tasks is to produce the Joint Conceptual Model of the Mission Space (JCMMS). Accordingly, one of our goals is to demonstrate that the current JCMMS object-oriented models are in harmony with the ontological paradigm. Clearly, the Ontolingua project demonstrated that it was possible and feasible to construct an OO layer on top of the basic KIF axioms. Cyc's CycL and MELD also support an OO view via the KE Text facilities. Because a subset of ontological axioms are OO in nature, any ontological work we do can interoperate with JCMMS schema-based systems provided that we adhere to their schema within our ontology. In addition, because the JCMMS is a fledgling effort, our projects have the opportunity to influence the development of JCMMS schema.

The US Department of Defense is convinced of the merits of standardization for the sake of interoperablity, hence they can be said to be amenable to standardized ontologies. They can rightly be viewed as being involved in the OO subset of the work, and the ontological community stands to reap great benefits from their standardization efforts. One of our long term goals then is to increase our influence within the JCMMS community so that we can facilitate JCMMS harmonization with mainstream ontological practice such as that represented by HPKB/Cyc Upper Level Ontology.

3. Benefits of Standardization: Syntax, Semantics, and Content

We believe that the syntax, semantics, and content of ontologies must be standardized in order to achieve interoperablity and to support emerging software agent technology and other software entities such as the simulation entities of our sponsor. In our view, both a standard syntax and conversion mappings between non-standard languages and the standard language are required. Content with respect to a particular domain need not be required to be present in an conforming standard ontology, but if that content is present, it must adhere in all ways to the canonical ontological description of that domain. Semantic standardization is perhaps the most rigid criterion. If a conforming standard ontology has a differing denotational semantics for a given term, there must exist conversion axioms which establish the semantic equivalence of the differing term definitions.

4. Integration with Other Existing Technologies

As stated above, the object-oriented paradigm can be viewed as being subsumed by the ontological paradigm. The two paradigms can communicate provided that they restrict themselves to the terms within the OO paradigm. The same is true with respect to the relational model. The OKBC implementors have shown that it is rather natural to create a relational database OKBC backend and thus allow an OKBC client to access relational data as if it were frame-based ontological content. The ontological model subsumes the relational model. Ontologies, object oriented databases, and relational databases can share schema and can therefore interoperate. The only restrictions are that the ontological paradigm may not communicate all of it's more expressive, subtle content. We are convinced that a natural way to facilitate integration with the OO paradigm is to design and implement translators and converters between standard OO specification and design languages (which are typically semantically light) and knowledge/ontology representation languages (which are semantically rich). Our hope and vision is that eventually the OO and relational communities can be convinced of the need for and the power of a knowledge representation which possesses a well-founded formal semantics, on which reasoning can be performed.

5. Modularity

Although this has not been a direct focus of our efforts, we are beginning to investigate techniques for top-down and bottom-up knowledge partitioning. Top-down decomposition is of course directly related to the notion of specific domain theories or so-called microtheories, i.e., functionally distinct areas which can be formulated as theories, the usual way of creating ontologies. However, in our experience, many domain theories share partially overlapping subsets of knowledge from other theories, which prompts us to also employ bottom-up partitioning methods to generate non-disjoint knowledge modules. These bottom-up derived knowledge modules can then be "carved out" of the original central knowledge repository (we are trying to follow the maxim to "represent once"), translated to other, target representation languages, compiled, and subsequently used by interacting agents to facilitate heterogeneous distributed reasoning.

6. Reuse

Our projects' knowledge integration into the HPKB/Cyc Upper Level Ontology has been a rather natural process. The axioms seem mature, properly broad in their coverage, and exhaustive in their coverage of the domain areas with which our projects were concerned. This is not to say that we did not have to do a large amount of specialization of the existing terms in order to get down to the level of granularity of our domain terms. But with only about 3000 terms in the Upper Ontology, this was to be expected. Perhaps the key to this type of integration is a willingness and ability on the part of the maintainers to improve the existing ontologies, as weaknesses become apparent. Authors of new ontologies must feel that their suggestions with respect to the older more general ontologies are heard. We found that we really did not get to test Cycorp's willingness to address our Upper Ontology related criticism, however, because the existing state of the Upper Ontology never precluded us from designing our lower level ontologies in the way that we wished. In short, we found it to be both well tested and well thought out.