

Experiences with using OWL in Military Applications

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Abstract. The United States military is continuing to research and is beginning to employ OWL-related information representation technologies. The Joint Explosive Ordnance Disposal (JEOD) Decision Support System (DSS) is using OWL to present relevant procedural information to warfighters. The United States Air Force (USAF) is experimenting with representing portions of the Foreign Clearance Guide (FCG) in OWL to support automated planning for transportation missions. The Defense Modeling and Simulation Office (DMSO) is experimenting with representing Computer Generated Forces (CFG) behaviors in OWL. These efforts have yielded “lessons learned” that can support future implementations of OWL-related technologies.

1 Introduction

Military organizations in the United States are beginning to recognize the potential for semantic markup of information. As with any new technology, appropriate applications of OWL must be identified (Lacy, 2005). Several efforts have been undertaken to research the benefits of marking up military information using the Web Ontology Language – OWL. These efforts include the:

- Joint Explosive Ordnance Disposal (JEOD) Decision Support System (DSS),
- Foreign Clearance Guide (FCG), and
- Computer Generated Forces (CFG) Human Behavior Representation (HBR).

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2 JEOD Decision Support System (DSS)

The military's Explosives Ordnance Disposal (EOD) mission includes rendering safe and disposing of any explosive material including the Improvised Explosive Devices (IEDs) that have caused many casualties in Afghanistan and Iraq. The United States military is experimenting with providing new advanced technologies to EOD technicians through a Joint EOD Advanced Concept Technology Demonstration (ACTD). The ACTD is responsible for a new JEOD Decision Support System (JEOD DSS) that includes a network infrastructure (JEODNET), a web portal (JEOD Portal), and the JEOD Mobile Field Kit (MFK).

2.1 JEOD Information Representation Challenge

One function of the JEOD DSS MFK is to provide Tactics, Techniques, and Procedures (TTP) information. One goal of the system is to present only relevant procedures to warfighters based on conditions and measures as they pertain to the warfighter's current environment. This TTP information has been historically structured as a hierarchical data set. By associating certain tasks and steps with conditions (e.g., time of day, weather conditions), information can be tailored to support the user's view and environment before presentation (Meeks, 2004) (Aviles, 2005).

Another challenge is to format the desired information in a manner that is form factor and operating system independent. (e.g., tablets and or laptops running any mainstream operating system) and to present the information only to authorized users. EOD TTP includes sensitive information. Some information is classified, and even the unclassified content has associated releasability restrictions or caveats.

2.2 JEOD's OWL Solution

The JEOD DSS used OWL to define an ontology for TTP and an ontology for conditions. TTP content was then marked up in RDF/XML to comply with these ontologies. Consuming applications used the TTP markup to provide functionality to users. The OWL representational ontology for procedures (i.e., TTP) includes support

for hierarchies of tasks, steps, and substeps that can have multiple forms of associated media and conditions. As the environment changes, TTP can be accessed and navigated in a non-linear fashion, unlike standard branching navigation usually associated with hierarchical data sets. This functionality is supported by a conditions domain ontology that describes conditions (e.g., “precipitation”) and extensible values (e.g., “raining”).

A Content Authoring Tool (CAT) was developed as part of the JEOD Portal to allow subject matter experts (SMEs) to author TTP content and associate the content with conditions. A JSR168-compliant portlet was developed to provide automated markup of content using the JEOD Portal. The CAT provides a user interface and an underlying Oracle database to capture TTP and relevant descriptions. TTP content is then exported into RDF/XML instance files that are compliant with the TTP ontology.

At present, the primary JEOD DSS software consumer of the marked up content is the Reference Assistant Tool (RAT) which is a plug in to the JEOD DSS MFK. However, JEOD plans to begin leveraging ontologies within other MFK and portal tools. JEOD is starting to migrate additional legacy information into an environment that is richly tagged and ontologically driven. JEOD also plans to use ontologies to drive data federation services. Conditions associated with TTP content are used for filtering and determining content relevance. This is accomplished using XSLT routines that process RDF/XML-encoded TTP content based on real-time conditions. Users can over-ride current system generated or sensor driven conditions in order to trigger a real-time re-publishing of the content.

2.3 JEOD Implementation Analysis

The CAT was critical for marking up TTP content. It made the RDF/XML syntax and associated TTP ontology transparent to the authors of the content. The TTP ontology is a representational ontology. Great value could be achieved by linking some of the marked up content with domain ontologies. For example, procedures that reference specific IED components could be linked to the IED ontology originally developed for another portion of the JEOD DSS.

XSLT routines perform run-time semantic-based filtering and formatting of RDF content. Eventually, inferencing routines capable of processing against multiple linked ontologies will provide more sophisticated functionality such as searching across domains to aggregate information.

3 Foreign Clearance Guide (FCG)

The United States Air Force's Air Mobility Command (AMC) recognized planning problems related to diplomatic clearances (Stedman, 2005). Rules regarding diplomatic clearances are described in a text document called the Foreign Clearance Guide (FCG) that is targeted at human readers. Currently, AMC mission planners manually calculate lead times, calendar constraints, and country restrictions to determine diplomatic clearance viability.

3.1 FCG Information Representation Challenge

This manual approach has led to problems. Each day, AMC loses over \$80K in fuel and one sortie daily due to diplomatic clearance violations. This results in a loss of over \$100K per day during contingencies. Indirect effects of these problems include:

- Lost crew time,
- Delays in transportation/supply system, and
- Disrupted flight/cargo movement schedules.

Air Force researchers recognized that making portions of the FCG automatically consumable by planning software could reduce the frequency of problem incidents.

3.2 ACT's OWL Solution

A research effort was conducted to markup FCG information and to develop a prototype software tool called the Automated Clearance Tool (ACT) to automate some of the AMC's processes using that information (Mulvehill, 2004) (Mulvehill, 2005). OWL ontologies were developed to support the representation of FCG information as

instance data. An Oracle database was developed to automate the process of creating the instance data files.

ACT is a decision-support tool that uses agents to support the processing of diplomatic clearances for Air Mobility Command (AMC). These ACT software agents use the OWL ontologies to reason about annotated diplomatic clearance-related data. The primary purpose of the ACT software agents is to use annotated FCG country data and local knowledge bases to automatically compute the amount of lead time that each country involved in a mission will require. Reasonable realizations of the lead time help AMC mission planners acquire the required diplomatic clearances. However, ACT also supports the overall diplomatic clearance process by providing services including:

- Processing diplomatic clearance mission requests,
- Monitoring key events in the process,
- Making changes to existing plans as needed, and
- Making requests for special clearances like blanket allocation and special clearance management easier.

In addition, ACT uses ontologies and semantic annotation to provide:

- Data-form consistency and update,
- Alerts to the user about environment changes (e.g., new missions, data changes),
- Graphical methods to display mission and/or diplomatic clearance problems, and
- The automatic generation of explanations of how calculations are performed.

3.3 ACT Analysis

Much of the FCG's content includes both contact information and geographic information. Although existing ontologies were leveraged to support representation of common concepts inherent in these two domain areas, such as latitude and longitude for geographical entities and phone number for contact information, a more standard ontology definition for these domains would have been useful.

Because of the intent to transition the lead time engine of ACT, the consuming Java agents were limited to performing only the inferencing required to support lead time computation. The notable exceptions were the inferencing by lead time agents about hazardous cargo and special clearances. For example, the FCG specifies what category of cargo is allowed or restricted for landing in or over-flight of a country. The lead time agents could use that information, and integrate it with information about cargo categories that was contained in the hazardous cargo brain book in order to determine if additional time was required to obtain landing or overflight clearances for the mission involved. Although a more extensive domain ontology for hazardous cargo would have been useful for making inferences about cargo, the ACT agents did use information about the hazardous cargo category codes to modify the requirements for diplomatic clearances for that mission.

Many rules, restrictions, and exceptions are specified in the FCG. At the time of ACT development, it was difficult to represent this type of information types in OWL. For example, an ontology might express the rule, “If a mission aircraft carries *hazardous cargo* and a *country* specifies that no mission carrying hazardous cargo can land, then each *airbase* associated with the *country* will not allow a mission carrying hazardous cargo to land”. Because there was limited rule reasoning support available in OWL at the time, the ACT user could create or modify some rules through the use of local ACT knowledge sources called “brain books”. Each of these brain books had an underlying model that described relationships among its entities (each entity specified through an ontology). Availability of a rules language (e.g., SWRL) would have drastically simplified the expression of conditions associated with certain diplomatic restrictions.

4 Computer Generated Forces (CGF) Human Behavior Representation (HBR)

Computer generated forces (CGF) are used to provide opposing, friendly, and neutral forces in simulations. Historically, the software to provide these capabilities has been hard-coded. However, new systems are increasingly data driven. One of the largest CGF systems ever developed is the OneSAF Objective System (OOS), and a major factor

in that system's development costs is Behavior Representation (BR). To represent behaviors, OOS uses hard-coded "primitive" behaviors that are assembled into composite behaviors using the OOS Behavior Composer tool. The composite behavior descriptions are represented in an XML-based Behavior Description Language.

4.1 CGF Behavior Representation Challenge

High costs in terms of both manpower and lengthy development time are associated with the current practice of developing new CGF behaviors for each new simulation (Gerber & Lacy, 2004). To date, there has been no standardization in the representation of behaviors to allow reuse. New behaviors are typically custom developed for each new simulation.

Along with the development of new behaviors is the resultant requirement, also costly, for each newly developed behavior, even within the same simulation, to go through the complete Verification, Validation and Accreditation (VV&A) process (Gerber & Lacy, 2004). So that portions of behavior could be reused in new behaviors without repeating the full VV&A process, there is also the need to be able to associate metadata to the behaviors, including such items as the approval authority and releasability. OWL ontologies could provide a means for standardizing the representation of the CGF behavior domain so that the behaviors could be more readily reused in composing new behaviors with a less extensive VV&A process needed.

CGF behaviors represent one type of information in the modeling and simulation domain. The use of OWL for interchanging various types of offline simulation data has been proposed (Blais, 2004). Data Interchange Formats (DIFs) currently specified using XML Schemas could be defined using OWL ontologies (Lacy, 2001). OWL could also support the discrete-event simulation community (Lacy, 2004).

4.2 CGF Behavior Representation's OWL Solution

The OOS was selected as a sample program to ground research into developing standard ontological behavior representations to support

composability of CGF behaviors (Lacy, 2003) (Gerber & Lacy, 2004). The representation used primitive behaviors and composite behaviors. The composite behaviors, composed of one or more primitive behaviors and possibly other composite behaviors, represented the temporal sequence of execution of the included behaviors while the primitive behaviors referenced the hard-coded software of the simulation to effect changes in the simulation. Both types of behaviors have associated metadata.

The ontologies developed were:

- A Behavior ontology to represent the behaviors, both primitive and composite,
- An Artifact ontology to represent associated metadata, such as general descriptions of the behavior, versioning information, and the VV&A records,
- A Concept Domain Metadata ontology to capture the representation of the entity performing the behavior, of its relationships to other entities and organizations, and of the conditions under which the behavior is appropriate, and
- A Variable ontology to support the representation of variables used by the behavior internally and as inputs and outputs.

Prototype software was also developed to demonstrate how OOS behaviors could be composed using OWL-compliant behavior representations. Additionally, a few behaviors from the Joint Semi-Automated Forces (JSAF) simulation were manually created as instance data files in an RDF/XML format committed to the developed behavior ontologies to demonstrate the capability of those behavior ontologies to represent behaviors from multiple simulations.

4.3 CGF Behavior Representation Analysis

The possibility of using OWL ontologies for standardizing the representation of composable CGF behaviors that could be reusable across simulations was demonstrated. This research demonstrated the tradeoff between representing information (i.e., a composite behavior) in OWL vice representing only the metadata about information (i.e., a primitive behavior) that is represented in another format (e.g., software

code, image). CGF behaviors are a very narrow/specialized domain. However, there may be an opportunity to leverage descriptions of process-oriented behaviors from fields such as web services and process modeling.

5 Summary Conclusions Based on Military Implementations

The military is beginning to use OWL. Although the military is commonly an early adopter, it must also be very careful in how it integrates new technologies because of the associated risks. A common challenge is the sensitivity, ownership, releasability, security, and provenance of marked-up information. This is typically associated with instance data rather than ontologies. Metadata properties for describing this type of information have proven invaluable.

Some pockets of the military community are more receptive to technology insertion than others. One way to assuage concerns about the use of OWL has been to emphasize its use of XML and describe OWL and RDF as standards for applying XML technology. This relates to an education and evangelism challenge that must be overcome for OWL to achieve widespread acceptance. As OWL based solutions evolve from performing richer search capabilities to leveraging semantic joins and then mature to include real-time reasoning agents, the advantages of using OWL over XML will become more apparent. Commercial OWL-compliant tools are also needed to convince some potential adopters of the language's maturity.

A successful technology insertion method for OWL in the military has been to focus first on providing an OWL "view" of some sample set of information by developing an ontology and marking up instance data. New functionality (e.g., inferencing) can then be demonstrated using the samples. As more military applications begin to adopt OWL technologies and benefit from its features, it will become easier to overcome technology insertion obstacles and focus instead on technological issues.

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