2004 Command and Control Research Technology Symposium
The Power of Information Age Concepts and Technologies

ACT - The Automated Clearance Tool: Improving the Diplomatic Clearance Process for AMC

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Topic for which Paper is being submitted: C2 Experimentation

Abstract

This paper describes a decision-support tool being developed to support diplomatic clearance processing for AMC (Air Mobility Command) mission aircraft. We describe the approach employed to design and develop the Automated Clearance Tool (ACT). Our work is one example of the types of decision-support tools and/or systems that can operate within, and leverage the concept of a "Semantic Web". The vision behind the Semantic Web[1] is based on the idea of *encoding* information so that computers or supporting software agents can use it to support a given application. A number of markup languages such as the Web Ontology Language (OWL)[2] have been developed to support web information encoding. Several tools[3] are being developed to facilitate the use of this language, including the Jena Semantic Web Toolkit[4] and RDQL query language[5].

Early adopters in government and business are using this approach to develop applications. In this paper we describe how ongoing advances in semantic annotation and the extension of XML with languages such as OWL have influenced the way ACT was designed and developed[6,7]. Also, we provide some recommendations about how semantically annotated data can be used to support command and control (C2).

Introduction

The United States Air Force Air Mobility Command (AMC) plans missions around the globe at a rate of more than 300 per day. For many of these missions diplomatic clearances are required for the aircraft and the crew. AMC mission planners currently depend on a variety of data sources that describe the requirements of a given country for diplomatic clearances. The clearance document most frequently referenced by AMC planners is the Foreign Clearance Guide (FCG), which is available as frequently updated web pages.

AMC planners also rely on information that they maintain locally. These local knowledge sources are known as "brain books". A brain book generally contains a variety of rules, preferences, constraints, and other data that the planners have determined to be of use in supporting their work. Some brain-book data is obtained by copying it from the FCG, while other parts of the brain books are modified to correspond more closely with data from other trusted sources, such as from U.S. embassy offices overseas. Later in this paper we describe the problem of determining whether to trust a given data source, the challenge that this presents to automated tools, and the approach we developed to manage the problem.

Of paramount importance in processing the diplomatic clearances for a given AMC mission is the determination of the time required to obtain a clearance from *each* country that the mission will fly over or in which it will land. This amount of time is referred to as the "lead time". Lead time is affected by many mission parameters, including hazardous cargo, landing, overflight, previous landing site, and next landing site. How these parameters impact the processing of a diplomatic clearance for a particular country is described in the FCG as text. Because performing a manual search and retrieval to find the needed data is often a time-consuming process, the AMC planners will often copy important restrictions from the FCG into one of their brain books. This practice works only until the FCG changes. Although the FCG web site does provide change-notification data, it is still a manual process to read the change, determine how it is different, and then update the brain books. Advances in annotation languages like the

Ontology Web Language (OWL), and agent-based applications like ACT can remedy this problem.

OWL is a standard language that is as simple as the Web's Hyper Text Markup Language (HTML) yet offers the power of semantic robustness. With OWL, the paragraph describing country constraints is not just a string of text but is semantically useful. For example, the latitude and longitude of a particular geographic location, when represented as a text string, is only useful for consumption by human problem solvers; but when that data is represented as a semantic instance of a geographic location data class with encoded longitude and latitude properties it can be *understood by a software agent*. Furthermore, the semantic similarity of two location instances in two contexts tells a software agent that the instances are describing the same thing. So that when the software agent discovers the same location data within a second data source that has additional context, the agent acquires that additonal contextual information about the location; for example the fact that it belongs to a certain country and resides in a certain region of the world. If necessary, the software agent can apply the additional knowledge to the first data source.

Semantic markup can be used to improve reasoning and search. To date, we have used OWL technology to annotate the primary data sources that are currently utilized by the AMC personnel who support diplomatic clearance processing. Our work demonstrates how this markup technology facilitates the ability of software agents to automatically interpret and use semantically annotated data from a web source. We have also developed a set of tools that allow the user to specify local knowledge (such as that contained in the brain books) as textual entries. The interface and underlying domain model and ontologies translate this input into a semantically annotated format that can be used by the software agents in ACT to compute the lead time required to obtain aircraft clearances, and to generate the internal documents that are required by AMC in order to manage and process aircraft diplomatic clearances.

Relevance to C2

In the development of ACT our goal has been to enable AMC planners at various levels of the command and control (C2) structure to submit requests for diplomatic clearances, reason about hazardous material restrictions, compute the mission-specific lead-time required to process the diplomatic clearances, and determine the constraints involved in obtaining a valid clearance.

To facilitate this automation we developed a set of ontologies to describe the problem domain, (e.g., country, aircraft, and hazardous cargo). In addition, we used some standard ontologies, such as the FIPS (Federal Information Processing Standard) country code ontology, from the ontology library available at daml.org (DAML is the precursor to OWL)[8]. We used these ontologies to support the annotation of both the local and external data sources used by an AMC planner. These ontologies and annotations allow the software agents within ACT to reason about the diplomatic clearance data, thereby automating a very labor-intensive manual processes, thus saving time and improving operational efficiencies.

In ACT each domain concept (e.g., "mission") is represented as an ontology. The ontology formally specifies a concept and its relationships to other concepts. A typical ontology contains a taxonomy and a set of inference rules. The taxonomy defines classes of objects and relations among them. For example, *hazardous cargo* may be defined as a type of *cargo*, and *airport ICAO codes* may be defined to apply only to *locations* of the type *airbase*. When classes, subclasses, and relations among entities are defined, they provide a very powerful medium for assisting in the interpretation of data by software agents.

Figure 1 shows part of the ACT *AMC Mission* ontology. It describes properties for an AMC mission leg that include:

- Binary (true/false) properties that indicate whether the leg can carry non-hazardous *cargo*, or *hazardous cargo*.

- *A destination* property whose value must be an *Airport*; where Airport is defined in the Airport-ontontology.

- A *destinationCountry* whose value must be a *Country*; where Country is defined in the FIPS ontology.

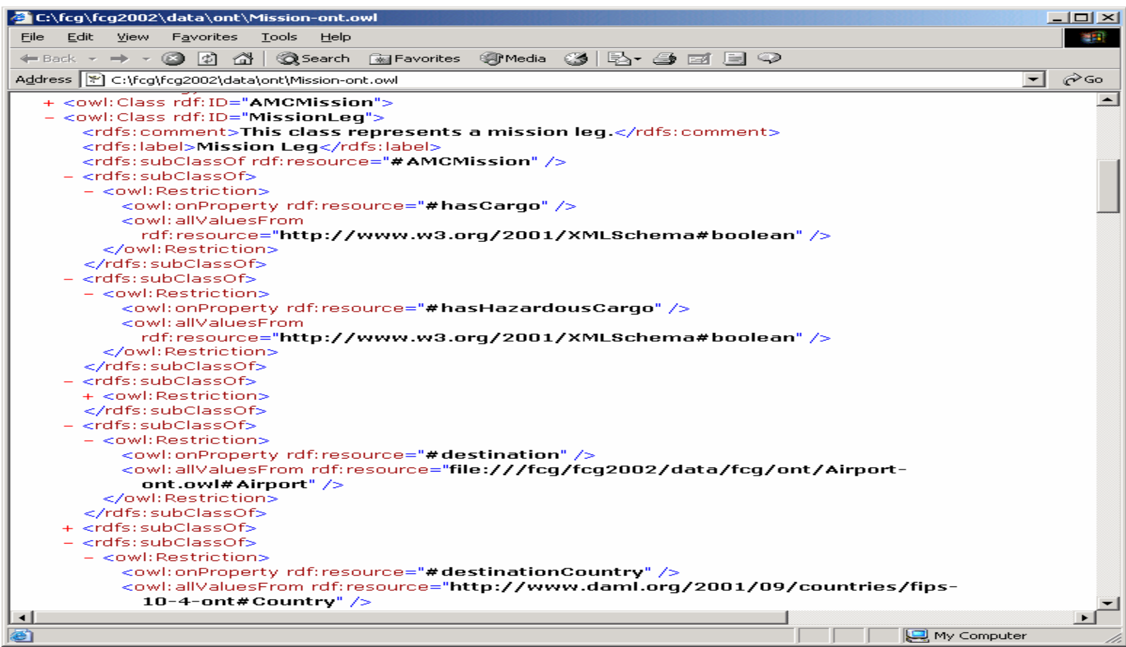

Figure 1 – Mission Ontology Fragment

A set of these related ontologies form a semantic web. This explicitly defined web can be used to support agent-based decision making and/or problem solving. Figure 2 shows a set (semantic web) of ontologies that are relevant in the diplomatic-clearance domain: *mission*, *airbase*, *country,* and *cargo*. Figure 2 also displays one ontology specialization, e.g., *hazardous cargo*. This set of ontologies (and several others) is used by ACT software agents to support data entry, to manage consistency, and to compute lead time.

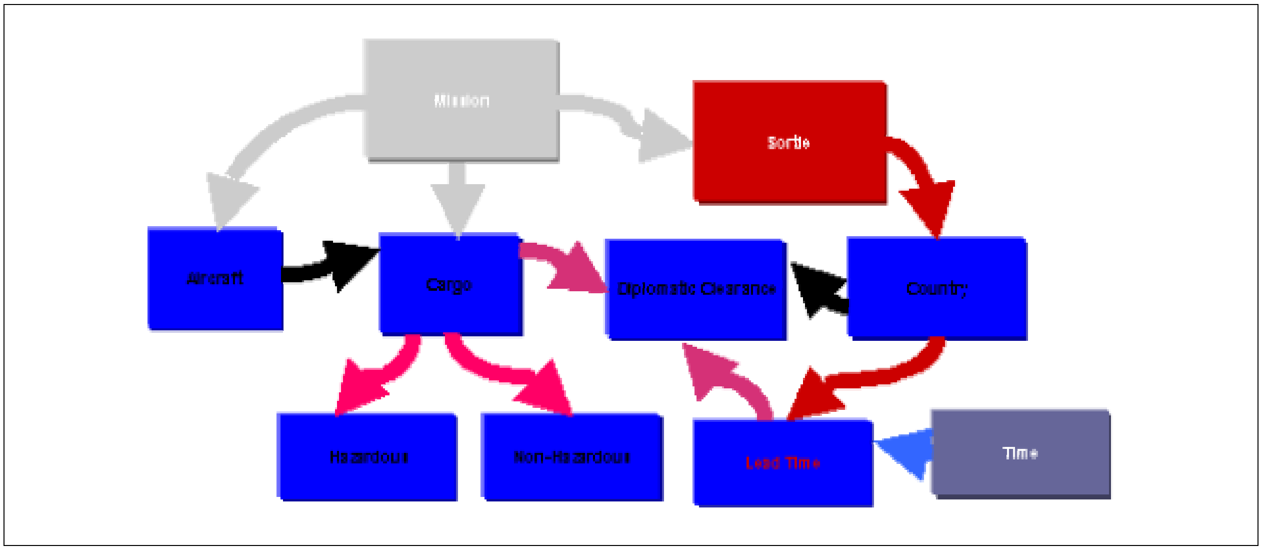

Figure 2 - Semantic Web of Ontologies

Inference rules in ontologies supply further power. 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”. In ACT the user can create or modify some types of rules through the use of the semantic brain books. Each of these brain books has an underlying model that describes relationships among its entities (each entity specified through an ontololgy). For example, the hazardous cargo brain book can be used to define hazardous cargo restrictions. Then, ACT software agents can interpret the data in this brain book as rules and use those rules to determine whether any restrictions are in effect for where the mission might land or for countries the mission might overfly.

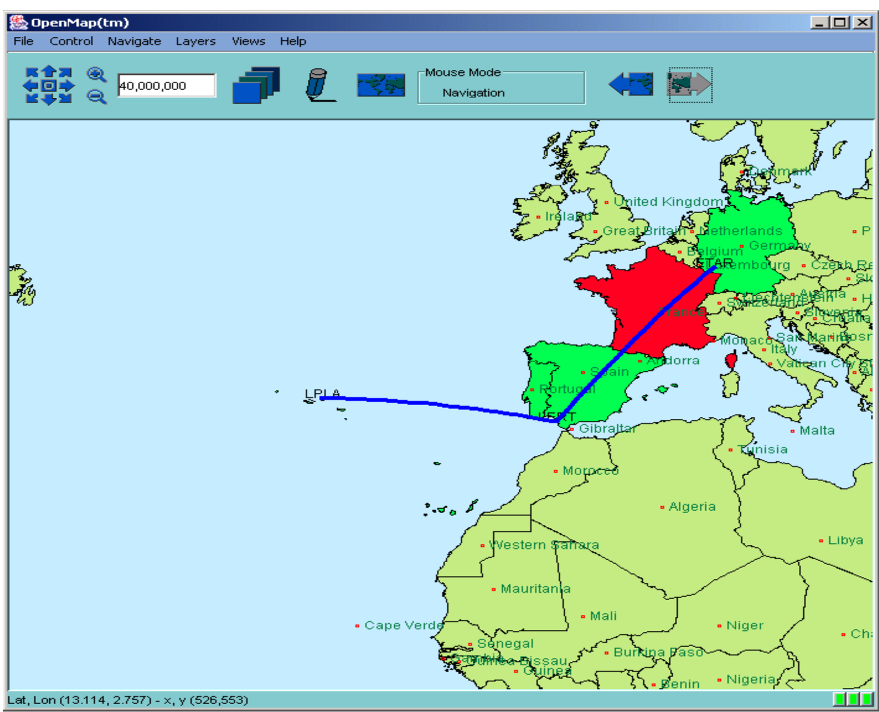

Figure 3 - Map Showing Diplomatic Clearance Restriction

The planner is alerted to these and other conflicts through the ACT interface. For example, the map displayed in Figure 3 shows a straight-line notional route for a mission. When a country is colored red it indicates that some rule associated with a diplomatic clearance restriction has been triggered and that a violation of the rule has occurred. The user can then determine the cause of the problem by referring to ACT's explanation-generation tool, the content of which is created automatically by ACT's software agents. The explanation created by the tool also contains a textual description of how and why a computation was made, and contains information about which rules were invoked and what sources of data were used. With this information, a planner can make adjustments to mission parameters until the mission is free of conflicts.

The Authors' Approach to the Problem

In today's organizations the power of the Internet is apparent, and having access to additional information from trusted third-party sites is extremely beneficial. Consider the requirements associated with traveling to a foreign country as an individual[9]. This is just a small sample of the types of problems that AMC planners face when flying aircraft to other countries. For AMC, there are many important considerations that must be addressed in order to provide clearances in a timely way. The current manual process is becoming increasingly inefficient and difficult to use, and these increased complexities demand a new approach to perform diplomatic clearance processing.

To date, many data suppliers have started to provide a more semantically meaningful structure to their Web data. Most useful is the application of the eXtensible Markup Language (XML) to incorporate contextual tags. Further, XML schemas are being developed in a variety of government and industry organizations to facilitate the standardization of XML terminology and usage.

The OWL semantic annotation language is a powerful extension of XML. OWL, its predecessor DAML+OIL[10] and similar languages[2] add the structure required to support automated reasoning. While tools exist to develop XML schemas and OWL ontologies, there is little guarantee that the resulting ontologies are valid for a given problem-solving domain. For example, some of the data in the FCG represents *concrete information* (such as airports, contact information, and holidays) while other data describes *rule-like information*. For the concrete data, the development of ontologies was rather straight-forward, and we were able to leverage data sources already defined in other, related domains. (An example of this is the FIPS country data, which provides a set of entities based on the FIPS country codes. See: http://www.daml.org/2001/09/countries.) In contrast, representation of the conditional rule-like information proved to be more of a challenge because a specific rule language for OWL is still under development[11]. One challenge involved the fact that the descriptions of lead-time requirements often contain qualifying information. For example, the lead time for a flight landing in country X can be qualified by whether the flight must land at a civilian airport or a military airfield, because these two cases can have different lead times. Currently this qualifying data is represented using a custom class that describes rules of this particular form. Unfortunately we cannot predict all possible rules, so we are investigating a method to represent textual conditions that require human processing.

Initially 15 country pages from the FCG were used by the BBN subcontractor Dynamics Research Corporation (DRC) to develop an ontological representation that was general enough to express the various ways of describing the data in all of the country pages. Several "foundation" ontologies were developed to represent the primary data elements required to compute lead time and to generate a variety of data forms used at AMC. These foundation ontologies were provided to the BBN tool developers so that they could analyze the ontologies from the perspective of an information consumer, e.g., a lead-time computing agent. This effort resulted in incremental revisions to the ontologies.

In addition to finding methods to handle concrete and rule-like information, we discovered that the software agents resident in ACT required a more granular representation in order to support their computation. For example, the FCG ontology tag "aircraft lead time" was revised to become two tags: "aircraft lead time quantity" and "aircraft lead time unit of measure" so that the software agent could differentiate between the quantity of days (e.g., 8), and the unit of measure (e.g., working days or calendar days).

In summary, the ACT system provides a framework for completing and submitting clearance request forms, monitoring key events in the process, and making changes to existing plans as needed in the dynamic mission-planning environment. It features a set of tools that communicate with the internal semantic representation to:

- Automatically complete forms to minimize repetitive entries.
- Alert the user to changes in the environment (new missions, data changes, new requests).
- Compute the required submission date for clearance requests based on individual country requirements.
- Display the mission and any clearance problems to the planner with a graphical user interface.
- Indicate problems associated with hazardous materials.
- Provide an explanation to the user about how decisions have been made.

Challenges to Automated Systems that Use Ontologies for Reasoning

This section describes our experience using a semantic annotation technology to develop the ACT decision-support tool, and provides some suggestions for other developers.

At the start of system design, DAML+OIL was the language available for semantic markup. Over time the language evolved, as did our software. Third-party tools were continuously under development, with some of them being abandoned, and others languishing unfinished. This provided an additional challenge to system development, as there were few tools of quality with which to work. Today, with the OWL language in its final form, the tools have matured. The current focus of the DAML program is to provide support to developers who use

OWL, and to foster the development of open-source tools (see: http://www.semwebcentral.org).

The fact that data contained in the brain books can differ from the data that is published in data sources like the FCG presents a problem of data-consistency. When software agents are developed to automatically utilize the data, there needs to be a way for the user to specify which data source is preferred and will therefore take precedence. In ACT we developed a preference parameter that lets the user choose which data sources to use for computation. Although this appeared to be a useful solution, upon further interaction with users we discovered that they need to be able to specify data sources for specific *instances* of data – not just for the entire set of data. Several approaches have been defined, but no method has been selected that offers the type of flexibility that the users seem to want.

Because ACT reduces manual processes and automatically computes important calculations, the agents within ACT are required to respond to data-source changes, and to provide alerts to the human planner when certain conditions exist. This problem challenges an automated systems to explain to the user how calculations were made. Our approach to this challenge was to develop an explanation tool that could use the semantic content of the system and the ontologies to describe how decisions were made. The tool we developed employs the ACT software agents to keep track of which data was used and which rules were executed to support the lead-time computation. The tool even provides a natural language text description of the analysis. Unfortunately, as this is not a tool that the users requested or are familiar with using, we have not met with success in getting the users to embrace its use.

Results and Future Directions

BBN, along with DRC, is working to develop and extend ACT. DRC has taken the lead in developing the ontologies that are used to interpret the data available in the FCG. BBN has taken the lead in developing the brain book applications, the forms, and the algorithms involved in computing the lead time.

During the course of this effort, the content and format of the FCG has changed (taking on an XML notation), the tools available to the AMC planners have changed (providing more automation), and the semantic annotation language has evolved. Our work to date with AMC indicates that the ACT tool and the capability that semantic annotation of data sources provides offer potential methods of adaptation to changes such as these.

Some recommendations about how semantically annotated data can be used to support command and control (C2) follow:

- XML has become a standard for representing and describing data. However, the granularity of XML markup appears to be consumer driven. Tools must be developed to allow consumers to annotate data sources, particularly textual data, to the granularity that their applications require, without corrupting the original source.

- User-friendly methods need to be developed to allow users to identify preferred data sources at a granularity that is as fine as a single term associated with a data provider, e.g., “temperature” from the source “weather.com”.

- Ontology development must be managed in order to maintain consistency across ontologies.
- Ontology mapping tools should be developed to provide a mapping between two representations of the same domain. This would facilitate linkages across existing ontologies and data sources.
- User-friendly methods need to be developed to adapt existing software agents to changing ontologies and/or data sources.

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