Information Interoperability for Coalition Operations – Status and Prospects

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SUMMARY

The need for information interoperability across coalitions is unchallenged, but how it is achieved, remains an open question. To examine this issue further the IST Panel supported a Task Group on the topic title to examine this issue, and to make recommendations on potential ways forward. The Group examined two related 'threads' in information interoperability - information exchange architectures and ontologies. Both relate to extant work within NATO on data modelling, and on the NATO Technical Architecture. In this paper key issues within each of these two threads are described and outstanding issues are presented.

1.0 INTRODUCTION

Background

Information interoperability across large diverse organisations remains a substantial challenge in both civil and military domains. The NATO RTO IST Task Group 010 - Coalition Information Interoperability, formed in Jan 2002, and concluding December 2004, has been examining the architectures and the emergent techniques for meeting this challenge. This paper is a summary of the major conclusions from that activity.

Overview

The groups approach to the problem has been to examine two parallel, but inter-related, themes:

A: Information exchange architectures; and

B: Data models and Ontologies.

The first represents the top-level schema for interoperability, the second the choice of interoperability representations that such a schema should employ. This paper presents the Groups collective view, and includes results and conclusions from a Workshop on the title topic help in Paris in November 2003 [1].

Objectives of the Task Group

- To better understand how to improve information interoperability across coalition forces;

- To highlight key commercial technologies and techniques that could support future information interoperability;

- To keep the methods simple and thus widely applicable and flexible;

- To better understand the complexity/scaling implications of extending interoperability (for example in the Network Centric Warfare (NCW) / Network Enabled Capability (NEC) settings; and

- To identify sets of tools that are useful for the longer term, and to identify gaps in capability.

Assumptions

Although communications is important in achieving Coalition Information Interoperability, it was not addressed by this group. Communications means are therefore considered and set as a fixed parameter in order to observe and understand the fluctuations of other variables of interest within the context of this group.

It was also assumed:

- That most 'systems' forming an information exchange domain[1] will be heterogeneous. Thus information exchange solutions <u>must naturally cope</u> with heterogeneity. Homogeneous information systems are most unlikely across a coalition.

- Systems will have different procurement and operational time-scales according to national priorities.

- Systems, and information exchange needs will be application domain related, e.g. to the military threat , to new forms of warfare, and to the supporting information and communications services.

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[1] We assume a number of heterogeneous systems being interconnected to form a larger information domain. This will create new information exchange demands, and impose new constraints on how the information is to be used, and how it might be interpreted by its users.

Problems and Directions

<u>PROBLEMS:</u> The problems for information management and exchange, within NATO (and many other organisations) are:

- Huge growth in information sources and types

- Huge growth in connectivity and required bandwidths

- Growth in user diversity - NATO is still growing – now 19 nations

- Warfare roles and participants changing

<u>but</u>

- There is no strong (or agreed) understanding of information representation, exchange, or management principles

- We are still struggling with information concepts.

In one sense the problem is so vast, that it might be asked what can any small group of investigators contribute to it? However with members who have experience of traditional architecture models, and the problems of developing large data models, and others with knowledge of ontologies, and WWW developments, it was felt that a useful input to the assessment of the military worth of these developments was possible.

<u>DIRECTIONS:</u> Under the heading of information exchange architectures we examined:

A1: Information interoperability domains

A2: Multiple exchange mechanisms

A3: Ad hoc interoperability.

Under the heading Ontologies we examined:

O1: Developments beyond 'traditional' data models

O2: Harmonisation and transformation of ontologies

O3: Tools and techniques

We still need to better understand:

- The practical scope

- Complexity of architecture, data model and ontology schemas [the scaling problem]

- Limitations

- The relative roles of ontology and data models – these are not conflicting models – the former is a natural development of the other.

The Interoperability Problem

In this paper we are interested in NATO interoperability – that is to describe what is needed between different domains (function, and/or ownership) for them to effectively inter-operate. It does not necessarily require that each domain itself has to be completely understood. Each component system does not necessarily have to share <u>all</u> its information with other systems. What is needed is a careful bounding of the interchanges needed to facilitate successful interoperability.

Secondly there is a degree of difference between interoperability in terms of access, for example via a web portal, -v- a fully interoperable schema, such as a 'common interoperability ontology', appropriately populated.

The simplest interoperability model is one in which all domains simply do their own thing, and interoperability gateways are developed as needed. This is generally considered to be an extreme view for interoperability solutions. The alternative view is to have one globally applicable interoperability exchange language. An interactive natural language understanding (NLU) interface would be ideal for this purpose, but NLU is not sufficiently understood to achieve this. Military messaging systems, data models, and now ontologies are attempts to provide the appropriate and increasingly powerful interchange languages.

Apart from the fundamental question of representational adequacy, other issues raised by the growth of information sources include:

- Control of information bases

- Standardisation of exchange processes

- Management [volume direction, archiving, etc.]

- How to maintain consistency

- Reasoning and exploitation of related information sources

Trends: The results emerging from various laboratories, and organisations, notably the WWW consortium, are indicating a new revolution in information use, exchange and management. It is a revolution that the military need to exploit. Whilst evidently much of the baseline technology for this will emerge as part of commercial practice, the deeper insights into the military domain that are needed to complement this, must come from military investment directly.

Ad hoc Interoperability

Concept: Coalition operations of today require an 'ad-hoc' way of interconnecting with the systems of unexpected external parties (like non-NATO nations and NGOs). Ad hoc interoperability is an attempt to define in the first place the lowest common denominators (LCD) needed for a basic level of interoperability between very different organisations.

Lowest Common Denominator Solution: At the lower communications layers it assumes adoption of standard established communications protocols, notably ISDN, IP, for mobility UMTS and related mobile telecommunications standards, and for local connectivity the emergent standards of IEEE-802.11 and Bluetooth.

At the middleware level it assumes adoption of well established and easily obtained systems and software, notably but not exclusively, Microsoft, Oracle.

At the information level it seeks simple interchange methods:

- Formatted messages

- Standard file exchange capabilities [e.g. via FTP]

- Standard sub-set of file formats

    - Word, RTF

    - JPG, TIFF

    - MPG, Mov

- Ascii File

- Screen scraping.

'Intelligent' Ad Hoc Networking: Whilst the LCD approach to Ad-hoc interoperability is a start, a much more adaptive interoperability capability is really what is needed. This is one that can deal with diverse systems that use different information exchange mechanisms and offer/require differently structured (or even unknown) kinds of information. In addition, 'ad-hoc' implies system interoperability should be realised simply and quickly.

Technology and products that enables solutions for ad-hoc interoperability are becoming available but need to be further researched and developed. For example interoperability described using ontologies supporting elementary reasoning, could be used to determine best routes to interoperation, by determining feasible common interconnection processes.

Ad-hoc interoperability especially requires the underlying information standards (data models) to be more flexible than is currently the case, so that new types of information can be added to the existing structure without extant data.

We believe these aspects of interoperability are worthy of further study, and that there are some interesting and potentially very valuable methods for achieving ad hoc interoperability.

Beyond these options we have examined information interoperability in terms of two related threads:

1. *Information Exchange Architectures;* and

2. *Ontologies.*

2.0   THREAD-1: INFORMATION EXCHANGE ARCHITECTURES

Questions

Should the systems talk directly or should there be an interface, or a third party, which does the mediation job for both parties?

Exchanging data and information as 'objects' is technically easily. However the languages are difficult to match because of different definitions interpretations and different contexts.

Should the interface be a NATO asset or a national asset?

Any NATO asset would depend from a central controlling authority. Standardisation management and the absence of any agreed information exchange language are problems.

What configuration control is needed?

Configuration control is essential for two parties to talk to each other. This is a well-known problem and is normally included in the early phases of new systems. The problem is to communicate without agreeing on a wide ranging, common fixed standard, but one that might for example be agreed every three years.

What is the role of Interoperability Testing?

Standards are not enough to have interoperable systems. Planning and testing systems together is generally useful. JWID is a good example of exploratory interoperability testing: JWID demonstration systems are increasingly interoperable, and have some success in application follow-through. The MIP also does interoperability testing every 2 years to assess the efficiency and performance of its MIP solution.

Information Interoperability Domains

To reach overall system interoperability within NATO, a single 'Esperanto' is not believed to be a sensible goal. An all-embracing information exchange standard is unlikely to solve the interoperability problem, because it will be:

- Too large;
- Its complexity and scaling properties are unlikely to be understandable, even empirically by a sufficient number of people; and
- Through-life management will be too extensive to sustain.

An alternative approach is to have smaller 'information domains', tightly identified with military areas of expertise, operation, or organisation. An inevitable consequence is multiple "exchange languages", each serving a specific "interoperability domain". Therefore some sort of *"NATO C3 domain structure"* is needed to facilitate interoperability *between* these domains. A short information analysis has resulted in a possible domain structure for NATO, consisting of 17 domains that more or less cover the area of coalition C3 information exchange (Figure 1) [2].

NATO would have to co-ordinate the development of these discrete domains, prescribing the scope of their information standards (exchange languages), but not developing them.

Current information exchange programmes within NATO (e.g., Bi-SC AIS, NATO Corporate Data Model, MIP) should evolve in such a way they will grow towards such a domain structure.
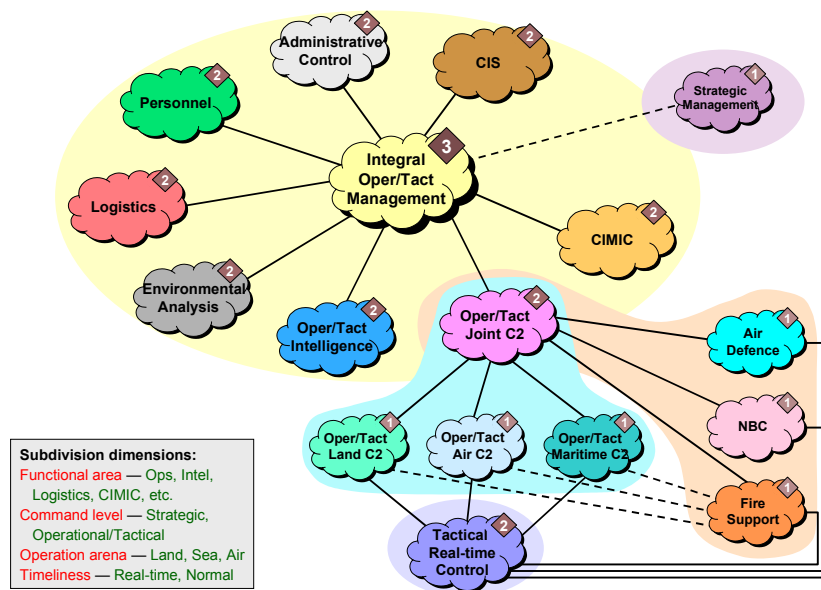

Figure 1: Proposed NATO Domain Structure.

We need Domain Experts first to help agree domain partitions, and to develop a domain management infrastructure, covering aspects such as:

- Agreed Description
- Domain structure
- Simplified DMs
- Overarching description

- Analysis of value of methods

    Important factors are:

    - relationships between domains
    - dependencies
    - evolution.

Multiple Exchange Mechanisms Between Domains

Overall interoperability within NATO requires *multiple* exchange mechanisms, which can be used *interchangeably*. The principle is shown in figure 2.

Some kind of 'layered' information exchange protocols (on top of some communication layer protocols) are needed that enables the seamless and simultaneous usage of different exchange mechanisms. This is shown in the figure, in which level-2 'clouds' are the mediators at that level, and 'cloud-3' mediates at the higher level.

No matter what exchange mechanism is selected, the *same* information standard should be used when two systems exchange information.
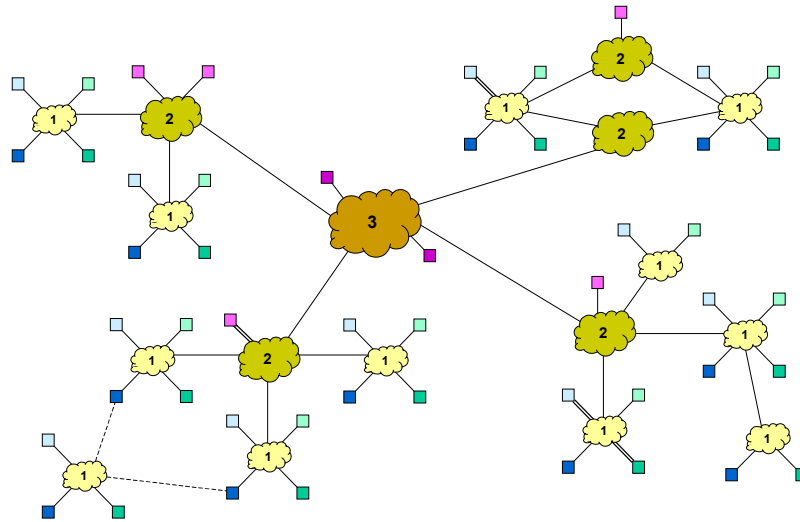
Figure 2: Hierarchy of Mediation Levels.

The process element of any integrated protocol for information exchange could be:

(1) Web-based exchange (using portals, web services),

(2) Exchange of XML-formatted messages (via e-mail),

(3) Automatic exchange of XML-formatted messages (using some simple protocol) and

(4) Automated database-to-database transfer (using replication or publish-and-subscribe mechanisms).[2]

Although the exchange mechanisms mentioned here are primarily meant to distribute *structured* information, it should also be possible to incorporate *unstructured* information (embed it in the structured information). In that way it can be exchanged by the same mechanisms. A fuller discussion of these issues is given in [2].

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[2] There are other forms of information exchange, for instance using cell phones, chat boxes or informal e-mail as a basic primitive, but these fall outside our scope of information interoperability.

Models for Interoperability

Questions: The favoured exchange method to date has been based on the use of data models, (and perhaps subsequently ontology models) but are these up to the task?

What are the limits of data models?

Data models are widely used as the foundations of ontology models, but we need to better understand the complexity issues of such models (how long to develop, maintain, relate model size to features of the domain etc.).

A data model is, in effect, means to capture part of an ontology, i.e. not as richly descriptive and not allowing computer 'reasoning' [3]. This appears to imply that an ontology will always be more complex than a data model for a given problem. The increased complexity in this case should solve some problems that the source data model itself could not compute/perform, but the complexity of such solutions is likely to be comparable.

Is the complexity of NATO's JC3IEDM overstated?

The NATO *Joint C3 Information Exchange Data Model* (JC3IEDM [3] development started in the 1980's with the ATCCIS Study, when no good tools, no mature web concepts, let alone ontology tools existed. Now, after 24 years, the ATCCIS Model has developed to a much wider ranging ambition for a joint C3 model, the JC3IEDM, which is being developed by the *Multilateral Interoperability Programme* (MIP). The MIP programme is supported by over 20 countries and other organisations, and therefore is positioned to play a substantial role in information interoperability. Do we think it can be done much more efficiently now, and if so how much more efficiently? The answer is that it would be more efficient now, but by what factor is difficult to say. Related questions are:

- *Do we understand the scalability of these models?*
- *Do we really understand the maintenance cost [as opposed to the creating cost]?*
- *How is flexibility/evolution handled?*
- *Would an OWL version of a DM better able to handle these aspects and if so why?*

At the moment the answers to these questions must await further experience.

Are ontologies any better with poorly structured information?

They could be better than a DM because of their (potentially) more powerful range of constructs, based on the use of Web standards, mentioned later in section 3, including the latter's ability to support logic based reasoning about the information.

There are various potential methods for facilitating the development of data models:

- The flexibility and readability of data models can be enhanced by using a mixture of generic and specific data structures.
- Translation between different data models can be simplified considerably by making use of a small common "data model framework", i.e. a 'core' data structure that predefines the most common and basic data elements for the NATO C3 area. This framework is different from the current NATO JC3IEDM, and has analogy with the various civil sector initiatives to define 'upper level ontologies'.
- Unstructured information can <u>and should</u> be easily embedded in structured information.

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[3] The distinctions are explained in more detail later in this paper.

Limited Abilities of Data Models: These include:

- *Scope*: what aspect have to be modeled and which ones have to be rolled out into specific systems covering special domains only?

- *Handling*: the bigger the application domain the better for interoperability, but the worse for maintenance, and overall comprehension.

- *Competence*: who is responsible-for/competent-to resolve conflicts?

- *Flexibility- evolution*: if new situations are mapped to new data model versions – who adapts the existing application systems?

- Data Models cannot handle weakly or arbitrarily structured information. Thus some means of incorporating unstructured information into the data model formats will always be needed.

3.0   THREAD-2: ONTOLOGIES

Introductory Commentary

What is an Ontology?

An ontology is a framework for ideas describing some coherent domain of operation or process – these ideas must come from domain specialists who understand both the domain, and what a particular system for which an ontology is needed is expected to do. The four NATO levels of interoperability are collectively a semantic concept: connected; shared information; shared awareness; co-ordinated action).

Ontologies are really a more logically structured form of data model, inasmuch as they have somewhat richer set theoretic definitions, with various inheritance and other relationships possible. These definitions are controlled such that there are strong constraints on definitions in order to maintain consistency. A further important feature is that ontologies normally support some degree of computer-based reasoning about the objects they describe. Such reasoning is based on first order predicate logic, and exploits various developments in this area over the last decade. It should be noted that most ontologies in use appear to have started with some legacy data model. This was then cast into an ONTOLOGY FORMAT, currently of course the new WWW consortium standard, OWL [4], and this then permitted the model to be expanded. It is entirely dependant upon the proposed applications for the data model whether this translation process is either effective or necessary. Each case must be assessed on its requirements.
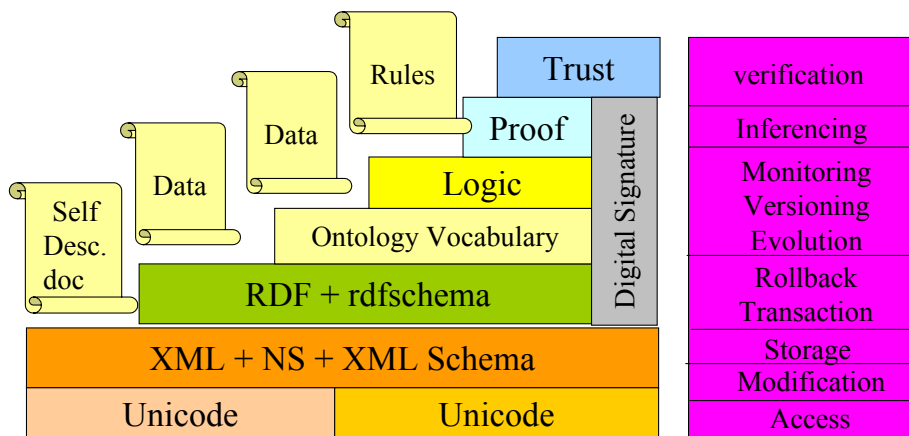
Source:*The Semantic Web*, Tim Berners-Lee, James Hendler and Ora Lassila, Scientific American, May 2001

Figure 3: Ontology Layer Diagram.

The position of ontologies in a layered view of system description capability is well described by the WWW's layer diagram of figure 3 [5]. The lowest layer represents the communications via an agreed addressing schema; *XML* etc represents a first level markup of data to facilitate its use; *RDFschema* provides a structured way of describing relationships. This level corresponds approximately to that achieved by many data model. Whilst data models can well describe essentially static structure and relationships, usually with a strong set theoretic flavor, they fail to completely capture the semantic and dynamic aspects. The ontology layer seeks to complete this capture. The logic and proof layers represent the ability to reason about the information, and the trust level covers issues of authentication and safety.

New warfare management initiatives (e.g. NCW) imply very significant increases in the ability to manage and exchange information. This relates directly to interoperability capability and has been stated by Alberts thus: *"The levels of network-centric capability defined in the NCW maturity model directly correspond to the degree to which interoperability has been achieved"* [6].

The 'modern' ontology development programme, originating in the WWW Consortium's ambitions for an 'intelligent' Web is the prime contender to investigate such extensions. If we accept that a semantic component is essential for information exchange in an NCW setting, then the exploitation of available Semantic Web technologies is essential for improving coalition interoperability. The primary differences between a DM and an ontology are that:

• The semantic representation of an ontology is richer; and

• The ontology permits a more powerful range of reasoning to be conducted on the information it represents.

There should be no special problems in representing a DM in the representations used by the current ontology proponents. The *Resource Description Framework* (RDF) appears to be well structured to cover the typical definitions and relationships used by DMs. The conclusion is that large and expensive though some data models may often be, don't throw then away – they are the foundations of most ontologies!

These comments still leave us with the argument that ontologies are perhaps the upper class of DMs, but so what? How are they going to make military interoperability easier, or better? That is still only a partly answered question.

Ontologies are meant to capture the semantics of a domain – to encapsulate what things in that domain <u>mean</u>. It must be understood that this is largely achieved by a structured form of object marking, and the names of the marks can be implied as adding semantic value. Such schemas can be used as the basis for much cleverer searches, or cleverer reasoning than with a DM, but the ultimate meaning of all objects and their relationships is for human interpretation. The computer enacting an ontology process is still supremely stupid. In developing this semantic aspect there are a number of significant questions, some of which the group has addressed:

The Semantics of Interoperability

Questions on Semantics

Can we capture the semantics of new military concepts (e.g. NCW, NEC[4]) in such a way that there is an overall understanding of what the problem really means?

There is no simple answer. The real answer is to take at least part of these problems, and to seek to create a working ontology, and assess it by peer review.

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[4] Network Centric Warfare; Network Enabled Warfare.

What is the role of use-cases in establishing an embryo ontology? Do we even think this can be done in a rich enterprise process, when the best tool – OWL does not encompass modelling dynamic processes adequately?

This is an area for further research and development. There is clearly a need at some stage to enable ontologies to embrace the concept of embedded models.

Can we determine a subset of semantic relations that are sufficient for military operations?

Are there any accepted methods of testing an ontology across peer groups? This is the old AI chestnut, where the proponents judged and announced their own successes, often misleadingly.

If we allow a number of different systems supported by their private ontologies, say all in OWL, how do we scope the difficulty of the harmonisation problem?

Harmonisation is still an ad hoc process. Again the best way of answering this question is by an increased research investment in examining real problems. The favoured approach is to take a set of problems/ domains that are not too large, and not too simplistic.

Why Semantics?

Despite the developmental state of ontologies, there are strong reasons for investigating their use in military interoperability. Ontologies can:

- Include an 'explanation component', making data processing more. flexible and easier for humans to accept. Ontologies can also handle fuzzy and unstructured information.

- Help in the representation and understanding of natural language.

- Assist in the understanding of structured information (from an unknown data model) as part of the information exchange process.

- Mediate over various national ontologies that will occur in the near term.

Experiences are already available: Is it possible to learn from other domains (e.g. biology, medicine, seismology).

Are ontology tools they sufficiently mature to be useful?

Useful tools and technologies now exist to support ontologies and semantic markup. Furthermore a new generation of tools are anticipated from the research laboratories from 2004 onwards [7]. Their utility to the (military) user needs to be demonstrated actively - how can this best be achieved? A more compete discussion of some of these issues is given in [8].

Status of Ontologies

Ontology systems are now being deployed - they work, people are using them, and they are economically supported. A US example is the National Cancer Institute ontology, which comprises thousands of entries, and is human driven, with a team of about 10 full time staff, who keep the ontology up to date [9]. Current ontology applications are generally in the data search, cataloguing or topic focus arenas. Another area of success in ontologies appear to be in business process expression languages. These ontologies exist and serve as benchmarks for what can be done, however the success of one particular ontology can seldom be used to infer much about the success of another one.

Standards: OWL is now a standard, submitted for approval by the WWW board on 18 August 2003. OWL is fully compatible with RDF[5], and RDF parses under OWL, and OWL scripts can be read into RDF.

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[5] RDF = Resource Description Framework

OWL forces graphs into trees that may not always be the most convenient representation. All these new tools add semantic modelling principles to XML.

Content Based Security Labelling: There are some interesting potential relationships between the XML schemas and the US led work on content based security labelling, (in which information objects are assigned some security value). A possibility for the future is rather than pre-assigned security classes, computable security values will be established which, depending upon the context of use, could be used to control security values and access/egress controls for various information exchanges.

Unified Modeling Language: An aspect that is not well covered is modelling, which is well represented as a capability by the OMG UML. Currently there is no formal link between UML[6] and OWL, but there appears to be a significant potential gain in being able to include complex process representations into OWL +UML (OWL++) format. This is because many of the key aspects of information exchange in a battlefield setting are process related, and take place in a time -critical setting. Notably target acquisition, targeting and interdiction.

Upper Level Ontologies: These are meant to represent high-level concepts that will range over a number of related ontologies. Obvious examples of ULO concepts are time, position, US view was that at this stage of the game that upper level ontologies (ULOs) are of little value, and the time spent on their development is a waste of time.[7]

Sample Data: Some examples of data tagging over a wide range of source material have been undertaken by IBM, and their results from over a million web pages, can be accessed on their web site.

Weak Areas: Those needing further development include multimedia search and other non-text sources (e.g. *Google* is poor in this area).

Mark-up Support Tools: Mark-up support tools that allow a substantial degree of automatic mark-up of input material are available, but their scope is limited. Unfortunately much more complex schemas require human intervention. COTS mark-up schemas when executed need considerable human parsing to give effective results. A number of these products have been evaluated by the US.

The view is that current market products are not yet satisfactory, but that the prototypes currently in a number of US laboratories represent a major step forward, and that these will be in the market place within 2 years (2005 – 2007).

4.0 WAY FORWARD

General

Overall despite the many questions still facing the developers of ontologies for military and civil system problems, there is a very strong optimism within the research community. This is based on their experience with both realistic problem solving, and the successes in developing and applying ontology description languages, as epitomised by OWL. Substantial further steps in information management and exchange can be achieved by following and exploiting this new work. Nonetheless it is useful to note that this optimism still has its doubters [10, 11].

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[6] UML = Universal Modelling Language

[7] The IEEE is host for the development of an upper level ontology.

Way Forward for NATO

NATO is increasing in size, and increasing in heterogeneity. The developments in information exchange technologies reviewed in this workshop indicate that for NATO there are many benefits in seeking to develop a series of key interoperability models that can be implemented as compact ontologies that can be used across several, or all NATO nations.

These key thrusts are:

- Understanding, and advocating a favoured information exchange architecture;

- Developing a suitable interchange model;

- Understanding the limitations of that model; and

- Developing a baseline of very simple interchange architectures for ad hoc interoperability.

These developments require the realisation that heterogeneous systems are inevitable, so that a compact, efficient way is needed to deal with this. A coalition programme on selected interoperability topic areas would be a good starting point.

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