Network Based Intelligence (NBI) - Knowledge Base Development and Use

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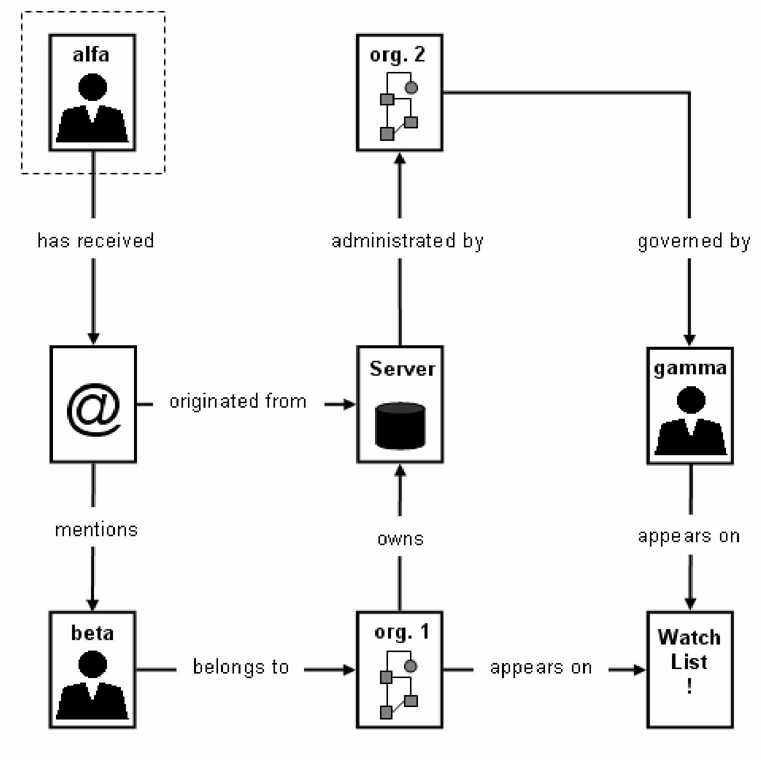

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Report title

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Abstract

To support Effect Based Operations (EBO) in the context of NBI, well-organized knowledge concerning target systems is required. The application of EBO will require structured and formalized knowledge in the form of a knowledge base. We have explored the possibilities of applying an existing process, the DCMF process, for Knowledge Base Development (KBD). From an NBI perspective the process seems to provide tools required for consistent and efficient KBD. A key aspect of a knowledge base, supporting intelligence-related analysis, is inclusion of uncertainty estimates. Information is most often associated with a degree of uncertainty, and representing this aspect in the knowledge base is crucial. An NBI related knowledge base needs the ability to handle both the uncertainty and the imprecision of the representation, access, and retrieval of information. Systems that combine the power of probability theory with the flexibility of fuzzy set theory seem to be building components for a future NBI. However, this will require not only further theoretical work on different formal theories, but also further efforts in the efficient implementation of these theories.

Keywords

EBO, Semantic Web, Knowledge Base, Uncertainty

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Nätverksbaserad Underrättelse (NBU) - Utveckling och användning av kunskapsbaser

Sammanfattning

För att stödja effektbaserade operarationer (EBO), inom ramen för NBU, krävs tillgång till välstrukturerad och formaliserad kunskap angående berörda system. Det krävs tillgång till kunskapsbaser. Inom NBU har en existerande process för utveckling av kunskapsbaser studerats närmare, nämligen DCMF-processen. Från ett NBU-perspektiv förefaller DCMF-processen tillämpbar för att på ett effektivt sätt bedriva utveckling av kunskapsbaser. En viktig aspekt av kunskapsbaser inom underrättelseområden är hantering av osäker information. Information är oftast associerad med en viss osäkerhetsfaktor och representation av denna är en nödvändighet för underrättelseorienterade kunskapsbaser. Inom NBU-projektet har denna aspekt studerats närmare. System som kombinerar styrkan hos sannolikhetsteori med flexibiliteten hos "fuzzy sets", framstår som potentiella byggstenar för ett framtida NBU. Detta kräver dock vidareutveckling av teorier, samt implementering och testning av dessa.

Nyckelord
EBO, Semantiska Webben, Kunskapsbas, Osäkerhet

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Abstract

To support Effect Based Operations (EBO), well-organized knowledge concerning the target system is required. The application of EBO will require structured and formalized knowledge in the form of a knowledge base. However, the development of such knowledge base is a non-trivial task, involving assembly of knowledge from multiple sources, estimation of credibility of sources, transformations to common formats etc. In order to handle these tasks in a consistent manner, and create a knowledge base that meets the requirements of NBI (Network-Based Intelligence), a process for Knowledge Base Development (KBD) is essential. It is desirable to use a process yielding highly structured and formalized knowledge, to enable machine processing and analysis.

We have explored the possibilities of applying an existing process, the DCMF process (Defense Conceptual Modeling Framework), for KBD in the context of the NBI. In this work we applied the DCMF process on an intelligence related scenario, i.e. the process transforms an unstructured text document to a highly structured and formalized form. For the time being, the DCMF process is not automated. The individual steps of the process require human work. However, the future goal is to develop tools that will automate the process as much as possible. Thus, the work of further developing the DCMF process will continue. From an NBI perspective the process seems to provide tools required for consistent and efficient KBD.

A key aspect of a knowledge base, supporting intelligence-related analysis, is inclusion of uncertainty estimates. Information is most often associated with a degree of uncertainty, and representing this aspect in the knowledge base is crucial. It is desirable to enable reasoning over uncertain and imprecise information to aid the commander in an EBO-context. We have explored the possibilities for representation of uncertainty in formal languages such as the Web Ontology Language (OWL), and the implications of its use within NBI. An NBI related knowledge base needs the ability to handle both the uncertainty and the imprecision of the representation, access, and retrieval of information. Systems that combine the power of probability theory with the flexibility of fuzzy set theory seem to be building components for a future NBI. However, this will require not only further theoretical work on different formal theories, but also further efforts in the efficient implementation of these theories.

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1 Introduction

From a general perspective, intelligence is knowledge and foreknowledge of the world around us. This knowledge is provided by intelligence organizations to help consumers, either civilian or military, to reflect on alternative options and outcomes prior to decision making. Intelligence production is complex, involving tedious collection of facts, their analysis, quick and clear evaluation, and timely dissemination to customers. In order to make the intelligence processes, within the military intelligence enterprise, more efficient, and to provide the foundation for efficient transition of today's intelligence enterprise towards the network-based defense (NBD), the concept of a network-based intelligence enterprise (NBI) has been developed.

The concept, or vision, for NBI outlines a trusted system capable of providing information of high value to various customers, to enable reaction in a pro-active manner. The NBI environment customizes information and knowledge according to the context of the intended user. This includes customization of information according to role, mission, technical equipment and physical environment of the user. Moreover, the vision outlines the intention to apply new information and knowledge management strategies and methods to enable new and innovative capabilities. Finally, the environment should be able to leverage its services during national, as well as international operations.

To realize the goals of NBI, we believe that a new approach to information and knowledge management is required. First of all, information and knowledge must be represented in both machine and human readable and interpretable formats. This will ensure interoperability and provide innovative possibilities for processing and analyzing information and knowledge. In this context, an ontology framework is required that cater for knowledge base development and use. An important feature of such ontology framework is management of uncertainty. Information and knowledge is most often associated with a level of uncertainty. Thus, it is vital to enable representing and reasoning with uncertain and imprecise information within the ontology framework.

The focus of the project during 2005 has been to explore fundamental aspects of an NBI-system, i.e. establishment of an ontology framework and investigation of management of information uncertainty. This work has been coordinated with ongoing projects within FOI, mainly the DCMF (Defense Conceptual Modeling Framework) project. Another important activity to consider is the work carried out within MNE (Multinational Experimentation), especially the KBD (Knowledge Base Development) track of MNE 4.

1.1 Purpose & Scope

The purpose of the project during 2005 was twofold. First, the project aimed at investigating and testing a process for structuring and formalization of knowledge, which is a fundament for KBD. The work focused on applying a process developed within the DCMF project on an intelligence related scenario. Second, the project explored the possibilities for inclusion of uncertainty estimates in the proposed knowledge representation language of NBI, i.e. the Web Ontology Language (OWL).

1.2 Motivation

Tool support for NBI will require access to structured and formalized knowledge of target systems, in the form of knowledge bases. Thus, it is of great concern to develop methodology for capturing required knowledge in a consistent and coherent manner, i.e. a process for KBD is required. An important feature of an NBI related knowledge base is support for representation and reasoning with uncertain information and knowledge. Thus, this must also be an intrinsic part of the KBD process. Given a well functioning KBD process, the goal of developing highly effective and useful tools for NBI (and EBO) is achievable. A knowledge base, supporting reasoning with imprecise and uncertain information and knowledge, enables complex analysis such as study of potential lines of development, given a certain type of situation, and conclusions what direct and indirect effects these developments may bring. This enables the intelligence community to act in a proactive manner.

1.3 Outline of the Report

Chapter 2 provides background information concerning NBI and how the NBI development is related to the work carried out within MNE 4. Further, this chapter presents essential components of a process for knowledge structuring and formalization, i.e. the DCMF process. Finally, the issue of uncertainty management in NBI is introduced and motivated.

Chapter 3 presents the experiences from applying the DCMF process on an intelligence related scenario to yield structured and formalized knowledge. Also, the applied process is described in greater detail. Further, this chapter presents methods to cope with management of uncertainty in NBI.

Chapter 4 discusses how an ontology framework, and methods for uncertainty management, can be used in an NBI-system, i.e. what kind of services can be built upon the framework to support the intelligence community.

2 Background

As mentioned in the introduction, the development of NBI has much in common with current efforts within the MNE 4 work (see 2.1). One of the goals of MNE 4 is to explore the possibilities for Effect-Based Operations, EBO (see 2.2). An important aspect of EBO is to have sufficient knowledge of the target system and efficient ways of analyzing and visualizing this knowledge. In this realm, the Knowledge-Base Development, KBD, track (see 2.3) within MNE 4 aims at providing this support. To develop a knowledge base, a process for structuring and formalization of knowledge is required. Section 2.4 describes such process.

2.1 Multi-National Experimentation – MNE 4

The Swedish Armed Forces are participating in a multinational development and experimentation program, referred to as Multinational Experimentation (MNE). US Joint Forces command has overall lead of coordination of these activities. The collaboration includes partners from Germany, France, Great Britain, Australia, Canada and other NATO members. Sweden and Finland participate as partial members. The directives from the Swedish Armed Forces give priority to development of Effect Based Operations (EBO), which is a major goal of experiment number 4 of the program, MNE 4. MNE 4 comprises the following lines of development:

- *Strategic Context and Conflict Termination*
- *Information Operations (IO)*
- *Effect-Based Operations Process (EBO Process)*
- *Effect-Based Operations Tools (EBO Tools)*
- *Knowledge Management (KM)*
- *Knowledge Base Development (KBD)*
- *Multinational Interagency Group (MNIG)*

2.2 Effect-Based Operations – EBO

At present, the development of the EBO concept mainly concerns the design of a future process for C2 on a strategic and operative level, but also how it is connected with the tactical level. A fundamental aspect of EBO is to shift focus from individual weapon systems and specific goals, to the desired effects of an operation. EBO employs a typical system's view and indirect methods to meet desired goals. The area of an operation, as well as actors within this environment, is regarded as a system whose state will be altered to fulfill assigned targets. Further, the EBO concept focuses on multifunctional operations, meaning that an operation is carried out using all means available (including diplomatic, military and economic means and information operations). EBO comprises four fundamental aspects:

- *Planning (EBP)*
- *Execution (EBE)*
- *Assessment (EBA)*
- *Knowledge Base Development (KBD)*

It is required that decision makers have access to sufficient data, information and knowledge in order to pursue EBO successfully. Thus, KBD is a cornerstone of EBO.

2.3 Knowledge Base Development – KBD

The basic idea of KBD is that individual partners of a multinational coalition share their information and knowledge covering an area of interest. The combined resource will constitute a knowledge base for the area of operation, which will be evolved with time given requirements from various decision makers.

The purposes of the KBD process are to build and maintain a knowledge base. The knowledge base is seen as available and releasable knowledge of participating nations, which is integrated through some form of Collaborative Information Environment (CIE). The CIE integrates stored knowledge as well as external resources in the form of Subject Matter Experts (SME) and Centers of Excellence (CoE).

2.4 Process for knowledge structuring & formalization

The development of NBI shares several goals with KBD, carried out within MNE 4. This includes aspects such as increased ability for information and knowledge sharing, within and between organizations, a high level of interoperability through a shared understanding of information, and a common environment for integration of various knowledge resources. The new directives for the Swedish Armed Forces, in terms of increased involvement in international operations, point at the importance of cooperation with other nations in developing a next generation intelligence system. Thus, it is beneficial to direct current research activities within NBI towards KBD within MNE 4.

A fundamental aspect of knowledge base development and maintenance is use of a consistent process for formalization and structuring of knowledge. This is an intricate part of building a knowledge base, as well as evolving and maintaining an existing knowledge base over time. The purpose of having a well defined process is to produce information and knowledge whose meaning is shared by all involved parties, thus, promoting sharing and interoperability of information extensively. In the context of NBI it is also crucial to enable automation, that is, the process is vital for creation of machine readable and understandable information and knowledge.

2.4.1 Defense Conceptual Modeling Framework – DCMF

DCMF as a concept originates from CMMS (Conceptual Models of Mission Space), originally presented by the Department of Defense (DoD). CMMS aimed at development of a framework for creation and management of conceptual models representing military operations. At FOI the CMMS concept has been studied and refined since 2001. In this work, a process for structuring and formalization of knowledge has been developed that could form the basis for KBD, namely the DCMF process.

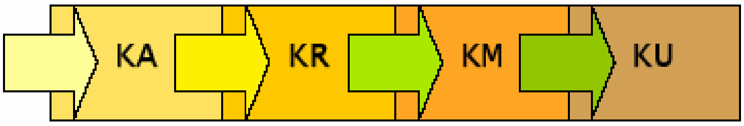

Figure 1. High level view of the DCMF process [Mojtahed & Garcia Lozano. 2004].

From a high level perspective the DCMF process includes four distinct phases (see figure 1), namely Knowledge Acquisition (KA), Knowledge Representation (KR), Knowledge Modeling (KM) and Knowledge Utilization (KU). The process relies on several ontologies, which are described next. In chapter 3 a more comprehensive description of the DCMF process is given.

2.4.2 Ontologies

In our previous report [Eklöf et al., 2004], ontology was defined at two different abstraction levels, i.e. the upper level ontology and the lower level ontology. An upper level ontology is a description of those entities, relations between them, and processes that are most characteristic and representative for the given problem domain. The purpose of such ontology is to reach a common understanding of the problem domain among those who are involved in a system development project. A lower level ontology is obtained by further developing an upper level ontology and by adding more details to it. Important issues concerning lower level ontologies include: the consistency, completeness and un-vagueness of the represented information/knowledge, and how well they are structured.

As we also pointed out in the previous report, the term "ontology" is referred to frequently in computer science, but the notion of ontology varies depending on the discipline. This is the case with a number of ongoing initiatives to define a standard upper ontology, e.g. IEEE Standard Upper Ontology Working Group (SUO WG) [SUO], and WonderWeb [WW]. "Upper ontology" and "lower ontology" are addressed in the initiatives, but with quite different meanings, as follows, [Semy et al., 2004] and [SUO]: An upper ontology is a high-level domain-independent ontology, characterised as representing those concepts that are basic, universal (generic) and of common sense. A lower ontology is a mid-level ontology or a domain ontology. A mid-level ontology serves as a bridge between universal concepts expressed in the upper ontology and domain specific concepts in a domain ontology. A domain ontology represents the concepts that are specific to a domain of interest. Figure 2 is intended to describe relations between different types of ontologies.

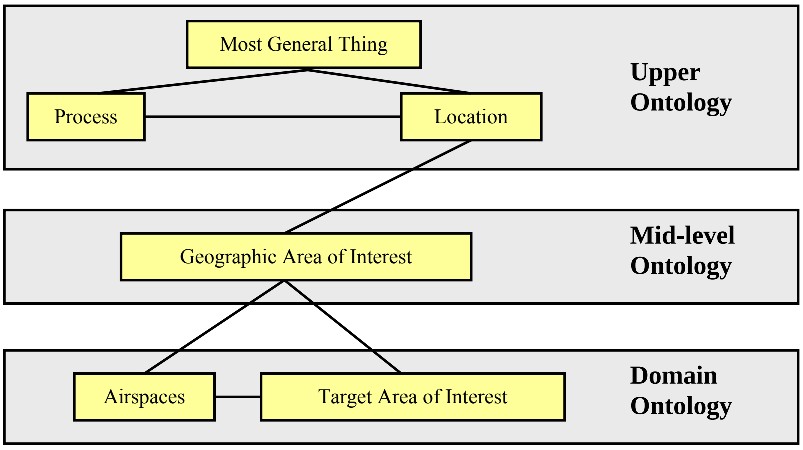

Figure 2. Ontology Categories [Semy et al., 2004]

Why do we need an upper ontology?

The readers may have noticed that the upper level ontology and the lower level ontology defined in our previous report belong to the domain ontology. Why do we then need, in addition to domain ontology, upper ontology and mid ontology? Summing up, it is to increase and ease shared common understanding, interoperability and reuse. An upper ontology is intended to define foundational concepts that may be used in several domains, thus providing a foundation (common knowledge base) from which mid ontologies and more domain specific ontologies may be derived. In this way, the knowledge and semantics already built into the upper ontology can be reused when developing these lower level ontologies. Furthermore, using upper ontologies is intended to ease the process of integrating or mapping lower ontologies. A mid ontology is intended, as mentioned above, to serve as a bridge between upper ontologies and domain specific ontologies.

The rest of this section presents an upper ontology named Suggested Upper Merged Ontology (SUMO) and a mid ontology called Land Command Control Information Exchange Data Model (LC2IEDM). While there are a number of candidates suggested as a standard upper ontology, we do not provide any extensive assessment of upper ontology candidates, but use SUMO without an in-depth evaluation. First of all, it was not the focus of this part of our study to provide this assessment. Rather, the focus was on the potentials and benefits of upper ontologies. Also, the upper ontologies are still in their development, and the ontological assumptions underlying different upper ontologies are not very clear (e.g., what are the impacts of adopting a specific ontological assumption?) [Semy et al., 2004], all of which makes it difficult to assess them. Finally, SUMO is one of the most well known upper ontologies today, which is sufficient for our purpose. LC2IEDM and SUMO has been selected to represent the upper and middle level of ontologies in the DCMF process. However, when testing the DCMF process the successor to LC2IEDM has been used, namely the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM). JC3IEDM is currently at the draft stage and contains minor changes from its forerunner [MIP].

Suggested Upper Merged Ontology - SUMO

SUMO is an upper ontology that has been proposed as a starter document for the SUO WG (Standard Upper Ontology Working Group), an IEEE-sanctioned working group of people from the fields of engineering, philosophy, and information science. The SUO WG is developing a standard, i.e. the Standard Upper Ontology, that will specify an upper ontology to support computer applications in areas such as data interoperability, information search and retrieval, automated inference, and natural language processing [SUO]. According to [Niles and Pease, 2001], it is estimated that SUO will eventually contain between 1000 and 2500 terms and roughly ten definitional statements for each term.

As mentioned above, SUMO has been a starter document and it is still in the development phase. The most recent proposed version is 1.72, proposed in December 2004. SUMO is designed to be relatively small so that assertions and concepts will be easy to understand and apply. Currently, the ontology consists of approximately 4,000 assertions (including over 800 rules) and 1,000 concepts. The knowledge representation language for the SUMO is the SUO-KIF (Knowledge Interchange Format) which is a predicate logic. A specification of the current version of SUO-KIF can be found at [SUO-KIF]. The ontology can be browsed online, and source files for all of the versions of the ontology can be downloaded from [SUMO1].

The structure of SUMO's top level concepts are illustrated in figure 3. The root node of the SUMO is 'Entity', and this concept subsumes 'Physical' and 'Abstract'. The former category includes everything that has a position in space and time, and the latter category includes everything else. Physical entities are further divided into 'Object' and 'Process'.

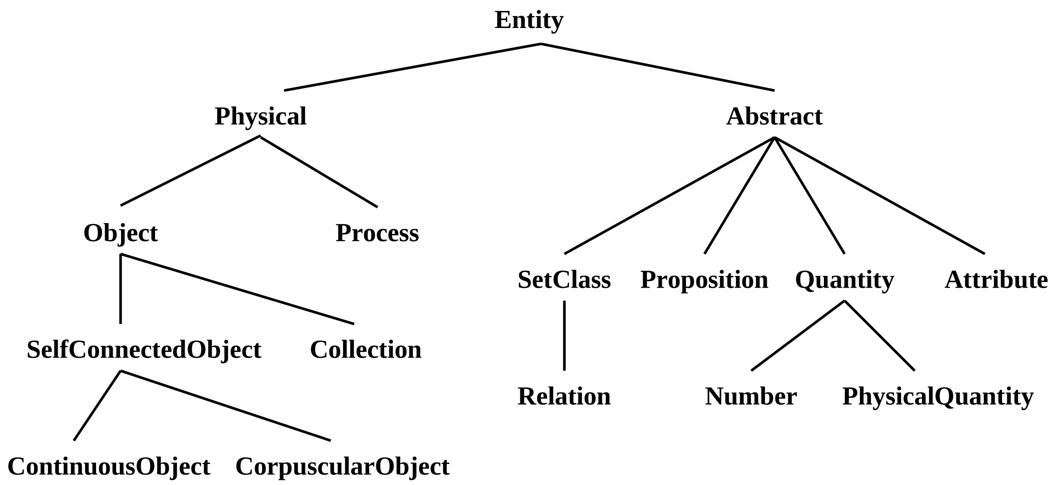

Figure 3. SUMO Top Level Structure [Niles and Pease, 2001].

Other general topics covered in the SUMO include: structural concepts such as instance and subclass; general types of objects and processes; abstractions including set theory, attributes, and relations; numbers and measures; temporal concepts, such as duration;

parts and wholes; basic semiotic relations; agency and intentionality [Nichols and Terry, 2003].

In addition to the SUMO core upper ontology, SUMO is also associated to a Mid-level Ontology (MILO) and a set of domain ontologies. These domain ontologies include [SUMO2]:

- Communications
- Countries and Regions
- Distributed computing
- Economy
- Finance
- Engineering components
- Geography
- Government
- Military
- Transportation
- World Airports.

Land C2 Information Exchange Data Model – LC2IEDM

LC2IEDM is a data model developed within the ATCCIS (Army Tactical Command and Control Information System) programme[1]. The ATCCIS programme aimed to identify the *minimum set of specifications, to be included within C2 systems, to allow interoperability between different national C2 systems* that are "ATCCIS-compatible". LC2IEDM is a product of the analysis of a wide spectrum of allied information exchange requirements by the 16 participating nations. It is intended to model the information that allied land component commanders need to exchange, and thus, serve as the common interface specification for the exchange of essential battle-space information. There are three models, with different abstraction levels, present in LC2IEDM, namely the conceptual, logical and physical. The Conceptual Data Model represents the highest level view of information in terms of generalised concepts such as Actions, Organisations, Materiel, Personnel, Features, Facilities, Locations, etc. This model is of interest to senior commanders wishing to verify the scope of the information structure. The Logical Data Model is obtained by breaking down (or sub-typing) the high level concepts. For example, a tank is an armoured fighting vehicle that is a piece of Equipment that is a piece of Materiel. The Physical Data Model provides the most detailed specifications that are necessary to generate a physical schema that defines the structure of a database. This is of primary concern to C2IS system developers, building LC2IEDM-compliant systems. Among the three models, only the Conceptual Data Model can be reasonably considered

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[1] ATCCIS started in 1980 and sixteen nations have participated in the programme: Belgium, Canada, Czech Republic, Denmark, France, Germany, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Spain, Turkey, United Kingdom, United States. The ATCCIS programme merged with the Multilateral Interoperability Programme (MIP) in early 2002, which has taken the responsibility of keeping and further developing the ATCCIS specifications.

as a mid-level ontology. Hence, we focus on the Conceptual Data Model, and in the sequel we mean the Conceptual Data Model with LC2IEDM. It should be pointed out that our presentation is directly based on the ATCCIS document [ATCCIS].

LC2IEDM encompasses the information requirements of several specific functional areas in the domain of land tactical operations. Since the data specific to a functional area may be considered as attached to the common core as "spokes on a wheel," the common-core data model was termed the Battlespace Generic Hub, or simply the Generic Hub[2]. Use of the LC2IEDM as the basis for functional area models is intended to ensure that the data, common across all areas, is viewed and structured in a standard way and that the data model views can be readily integrated into one coherent structure. The interdependence of the LC2IEDM and the speciality subjects of functional areas are illustrated in figure 4.

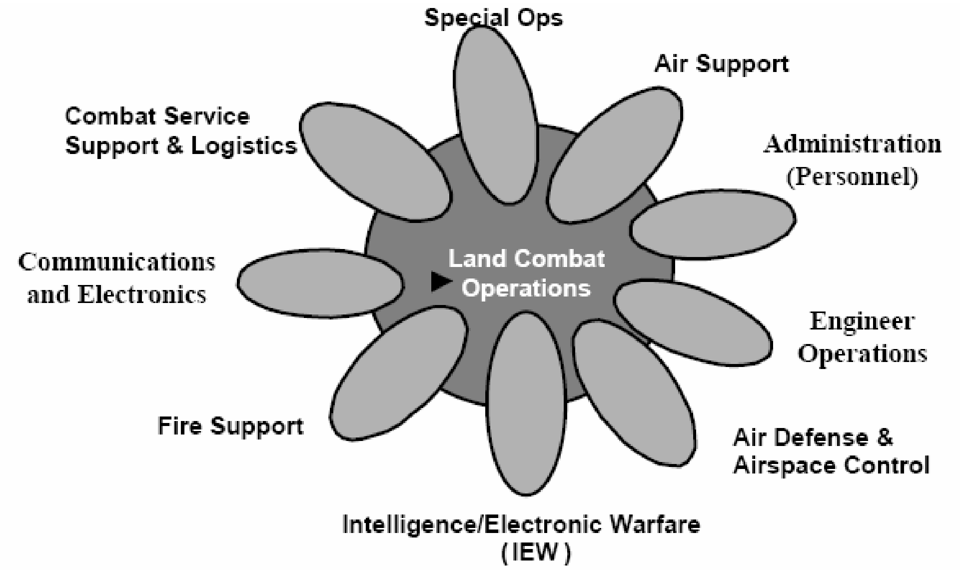

Figure 4. LC2IEDM and its relationship to functional areas [ATCCIS].

LC2IEDM was designed to represent two separate but related aspects of the battle-space. The first is the *objects* of the battle-space. This includes characteristics of the objects themselves, their status, their locations, their interrelationships, capabilities, addresses, and other properties. The other is *activities* on the battlefield. This encompasses operational plans and orders, reports of current activity, and predictions or anticipation of future activity.

The most basic building block in LC2IEDM is an entity, i.e., any distinguishable person, place, thing, event, or concept about which information is to be kept. Properties or characteristics of an entity are referred to as attributes. The entire structure of LC2IEDM is generated from twelve independent entities, that is, entities whose identification does

[2] For these reasons the data model was formally known as the Generic Hub. The name was changed to LC2IEDM in 1999.

not depend on any other entity. All other entities are dependent entities. Independent entities are listed and defined in table 1.

Table 1. Twelve independent entities and their roles [ATCCIS].

Entity Name	Entity Definition	Role in the Model
ACTION	An activity, or the occurrence of an activity, that may utilise resources and may be focused against an objective. Examples are operation order, operation plan, movement order, movement plan, fire order, fire plan, fire mission, close air support mission, logistics request, event (e.g., incoming unknown aircraft), or incident (e.g., enemy attack).	Dynamics (How, what, when something is to be done, is being done, or has been done.)
CANDIDATE-TARGET-LIST	A list of selected battlespace objects or types that have potential value for destruction or exploitation, nominated by competent authority for consideration in planning battlespace activities.	Information to support ACTION.
CAPABILITY	The potential ability to do work, perform a function or mission, achieve an objective, or provide a service.	Indication of expected capability for types and actual capability for items
CONTEXT	A reference to one or more REPORTING-DATAs.	Packaging of information.
LOCATION	A specification of position and geometry with respect to a specified horizontal frame of reference and a vertical distance measured from a specified datum. Examples are point, sequence of points, polygonal line, circle, rectangle, ellipse, fan area, polygonal area, sphere, block of space, and cone. LOCATION specifies both location and dimensionality.	Geopositioning of objects and creation of shapes (Where)
OBJECT-ITEM	An individually identified object that has military significance. Examples are a specific person, a specific item of materiel, a specific geographic feature, a specific co-ordination measure, or a specific unit.	Identifying individual things. (Who and What)
OBJECT-TYPE	An individually identified class of objects that has military significance. Examples are a type of person (e.g., by rank), a type of materiel (e.g., self-propelled howitzer), a type of facility (e.g., airfield), a type of feature (e.g., restricted fire area), or a type of organisation (e.g., armoured division).	Identifying classes of things. (Who and What)
REPORTING-DATA	The specification of source, quality and timing that applies to reported data.	Support for the reporting function.
RULE-OF-ENGAGEMENT	A specification of mandatory guidance for the way a given activity is to be executed.	Support to ACTION.
COORDINATE-SYTEM	A rectangular frame of reference defined by an origin, x and y axes in the horizontal plane, and a z-axis. The vertical z-axis is normal to the xy-plane with positive direction determined from the right-hand rule when the x-axis is rotated toward the y-axis.	Support to LOCATION for specifying relative geometry.
REFERENCE	An allusion to a source of information that may have military significance.	Pointing to external information in support of REPORTING-DATA.
VERTICAL-DISTANCE	A specification of the altitude or height of a point or a level as measured with respect to a specified reference datum in the direction normal to the plane that is tangent to the WGS84 ellipsoid of revolution.	Support to LOCATION in specifying elevation.

Further, nine of the entities are considered to be keys. Key entities and their relationships are illustrated in figure 5. A dot at the end of a relationship line denotes “many.” The relationships shown in this diagram are all many to many. For example, the relationship between OBJECT-ITEM and LOCATION is to be interpreted as a pair of statements that an OBECT-ITEM may have zero, one, or more LOCATIONs and that a LOCATION may apply to zero, one, or more OBJECT-ITEMs. For more details, the readers are referred to, e.g. [ATCCIS].

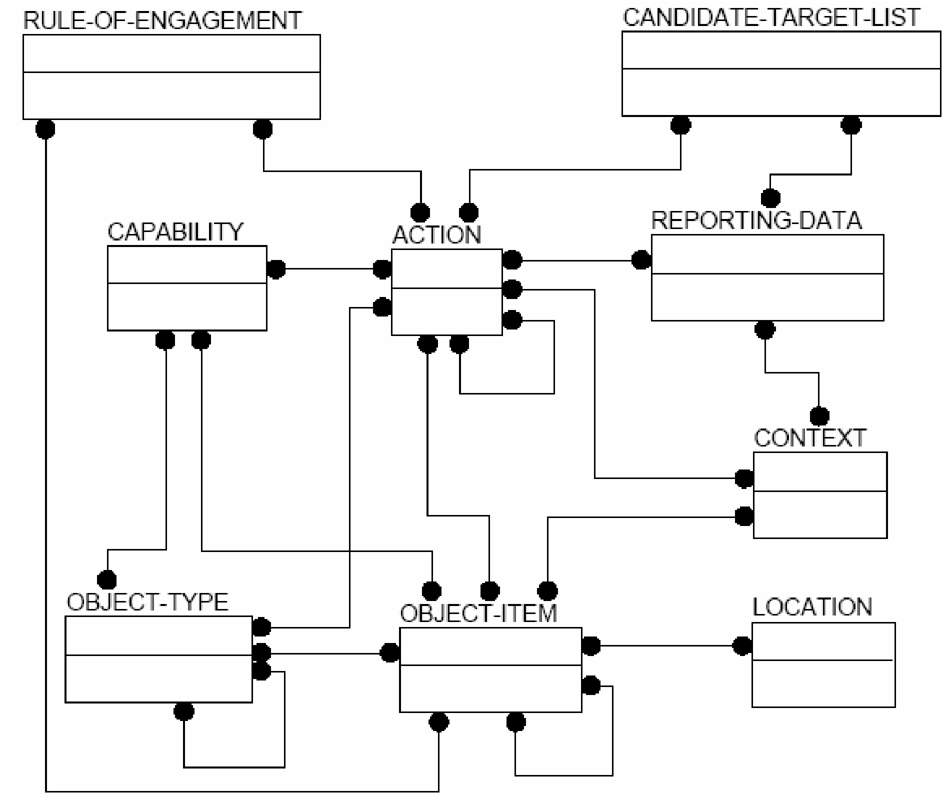

Figure 5. Key entities of LC2IEDM [ATCCIS].

LC2IEDM provides a well-structured and extensive data model which can be considered as a mid-level ontology for the military domain indeed. To our opinion, however, a non-trivial drawback is embedded in the model. It is the separation of OBJECT-ITEM entity from the OBJECT-TYPE entity. This is on the contrary to the generally accepted modelling principle that an object type is a collection of object items of the same kind, i.e. those that share the same properties and behaviours. In this way you don not need to specify the properties and behaviours for every individual object item. In LC2IEDM both OBJECT-TYPE and OBJECT-ITEM are decomposed into subtypes, and the decomposition is made redundantly: OBJECT-TYPE is subdivided into ORGANISATION-TYPE, MATERIAL-TYPE etc., and OBJECT-ITEM correspondingly into ORGANISATION MATERIAL etc. As well known, it is not only a less efficient way of modelling, but also more difficult to maintain such model. There are additional elements in LC2IEDM that are not very clear, e.g. the use of UML-like diagrams in a way not intended by UML, and the concept of object status. But discussing them with a reasonable depth will go into technical details and is beyond the scope of the report.

2.5 Information uncertainty

2.5.1 Uncertainty and imprecision for NBI

Relevant intelligence information may originate from numerous sources, some of which are well-established, such as geography models ("map data"), others may be human intelligence information, yet others come from sensors and other physical devices, including mobile phones and payment terminals.

In general, when modelling situations we have to deal with uncertainties. Identification of threatening behaviours, such as criminal agents' likely courses of action, are examples where a degree of uncertainty is always involved. The intelligence process of connecting the dots, interesting pieces (or clusters) of information, may lead to generation of several hypotheses with different degrees of certainty. For example, a process of connecting potential criminals and their resources in a current situation, to different presumptive targets, is a process where reasoning under uncertainty is involved. Thus, intelligence representation languages need the ability to express imprecise and uncertain information. Currently, standard semantic description languages, such as RDF and OWL, are unable to represent uncertainty in a uniform and consistent manner. In systems based on traditional logic, representation and reasoning can only be performed in terms of *true* and *false*. Due to imprecision, concepts often overlap each other and a problem of discerning classes arises. In most real world situations we face different kinds of knowledge that can be uncertain and/or incomplete. In other words, we may be certain that some statements are true only to some degree. One of the purposes of NBI is to provide decision support for the analysts in the process of reasoning under uncertainty, concerning information from several different sources.

It is usually easy to define entries in an intelligence system, such as a piece of text, the name of a person, a set of coordinates and a time. But how should the uncertainty, or likelihood, of each of these entities be estimated and entered in the system? Information in intelligence databases has different levels of uncertainty. Database management rules perhaps dictate which information may be entered in a specific database depending on its degree of uncertainty. Information might be moved to another database, or another information category within the same database, when its uncertainty changes due to the arrival of new, related information. Thus, it is not enough to tag information according to a specific ontology. Uncertainty must be represented in some way and must accompany an information item during its entire lifetime. However, representation and categorization of uncertainty, in order to make a machine able to reason about potential relations, is a complex task.

Methods for finding hidden relations may rely on looking at different "dimensions" of a problem. It may, e.g., involve time-line analysis where time-stamped entries are temporally ordered, in order to find potential connections. Networks of relations between people will have to be set up: who knows whom, who has family relations with whom. Figuring out nested business connections is a similar issue. These approaches may all be different dimensions of the main problem to be solved. By isolating the dimensions of the problem and looking at each dimension in turn, the work becomes more manageable. User based filtering of noisy information, such as vague relations, could be achieved by *representing and dealing with uncertainty in machine interpretable manner*. However, to date there are no tools available that can support the analyst in this task. In this section we present our current efforts in dealing with uncertainty in OWL for NBI.

In our previous report [Eklöf et al., 2004] we addressed the uncertainty issue as a future research challenge for NBI. Here we present the current and related research in this area. In section 2.5.2 we start by briefly explaining the conceptual difference between uncertainty and imprecision, moving on to the formalisms for expressing uncertainty and imprecision. In section 3.2 we relate this topic to NBI and give an example of how those concepts can be used in an NBI environment. As OWL is the proposed knowledge management language for NBI, we propose approaches based on OWL for dealing with uncertainty and imprecision.

2.5.2 Fuzzy Logic and Bayesian Networks

Here we explain two traditional approaches for dealing with:

- Imprecision – Fuzzy Sets [Zadeh, 1965]
- Uncertainty – Bayesian Networks [Jensen, 1996]

At a first glance, one may think that there is only one type of uncertainty in information. However there are different types of uncertain information. In table 2 you can find the translation (English – Swedish) of the most frequent terms used in papers discussing issues of uncertainty.

Table 2. Translation of some common terms used when dealing with vague information.

No.	English	Swedish
1	ambiguous	tvetydlig
2	inconsistent	motsägelsefull
3	incomplete	ofullständig
4	imprecise	oprecis, onoggran
5	uncertain	osäker
6	vague	vag

In some cases it is possible to classify the type of uncertainty in one of classes numbered one to five. The weakest form of uncertainty is the classification that information is vague. This case is more general than any of the other cases in table 2.

In the following example by [Smets, 1999] the difference between imprecision and uncertainty is explained in terms of the following statements:

1. John has at least two children and I am sure about it.
2. John has three children but I am not sure about it.

In statement 1, the number of children is imprecise but certain. In statement 2, the number of children is precise but uncertain. Both aspects can coexist but are distinct. It is often the case that the more imprecise, the more certain, and the more precise, the less certain. The uncertainty aspect is more of a property of the analyst in the NBI case. The imprecision aspect is more of a property of the data itself.

Fuzzy Set Theory

Fuzzy sets are formalisms aimed to represent imprecision. All humans have the experience of imprecise instructions such as: "Give me little more sugar" or "Park the car over there". However, the representation of imprecise knowledge in a computer understandable manner may turn out to be a difficult, but manageable, process. "*Most tactically-significant events require a more robust and flexible means of expression. This can be achieved by the use of fuzzy logic*", [Mulgund et al., 1997]. Fuzzy sets are generalization of the conventional set theory. The conventional set, called crisp set, can be embedded into a fuzzy set.

The idea behind fuzzy sets is introduction of a characteristic function, Φ_m. Let us first explain the crisp case where the characteristic function (Φ_m) is used to describe crisp set *M*. The assumption is that A is a subset of a larger set, Ω, containing the states, x, of interest.

$\Phi m(x) = 1$ if $x \in M$

$\Phi m(x) = 0$ otherwise ($x \notin M$)

The crisp set *M* can be represented by the function $\Phi m(x) : \Omega \to \{0,1\}$. Φ_m equals one, if *x* is a member of *M*, or zero if *x* is not a member of *M*. In fuzzy set A, the fuzzy characteristic function, Φ_a, can take all values in the interval zero to one. Set A can be represented by the function

$\Phi a(x) : \Omega \to [0,1]$

That is, the fuzzy function represents a degree of belonging to A. By using fuzzy set theory we can express the degree of belonging of a subject to an object. For example, instead of just expressing that a certain person is a member of an organization we can even express, by using fuzzy set theory, to what degree this person is member of the organization.

In Figure 6 we have depicted a fuzzy function that represents a person's membership degree of a certain person belonging to a certain organization. This membership degree depends on states x. A state can be a number of how often a person attends meetings. With $\Phi org(x)$ we denote membership degree of a person belonging to an organization

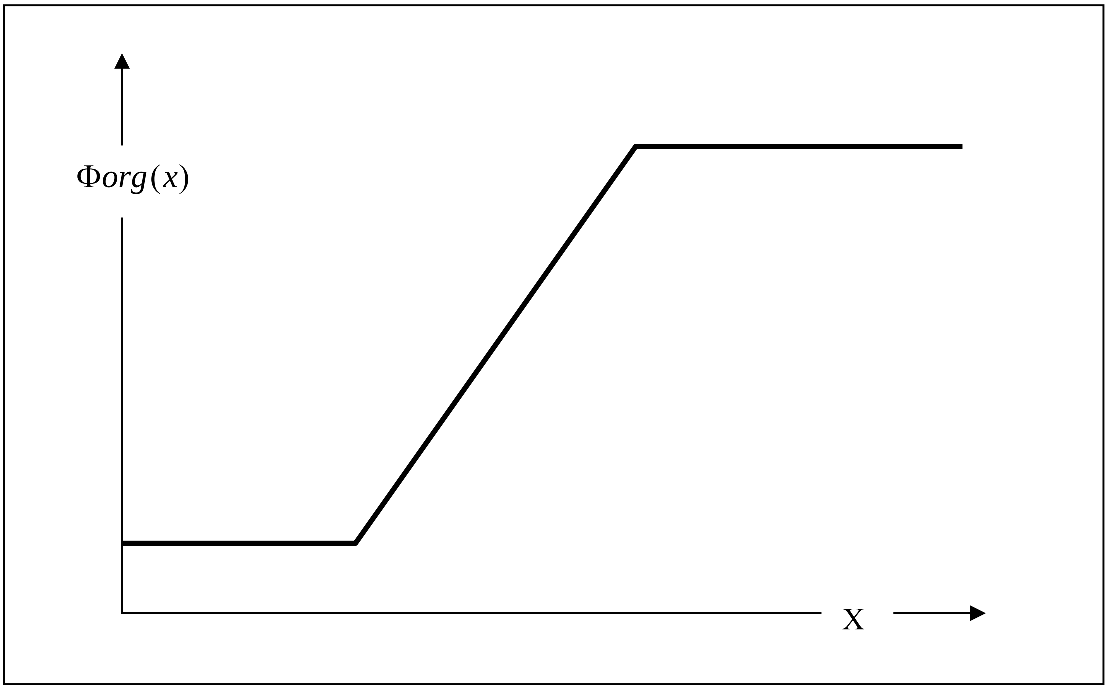

Figure 6. Fuzzy membership function with continuous values.

Alternatively, as in figure 7, the function $\Phi org(x)$ can be defined using qualitative (linguistic) states x, where x = {never, rarely, often, always}.

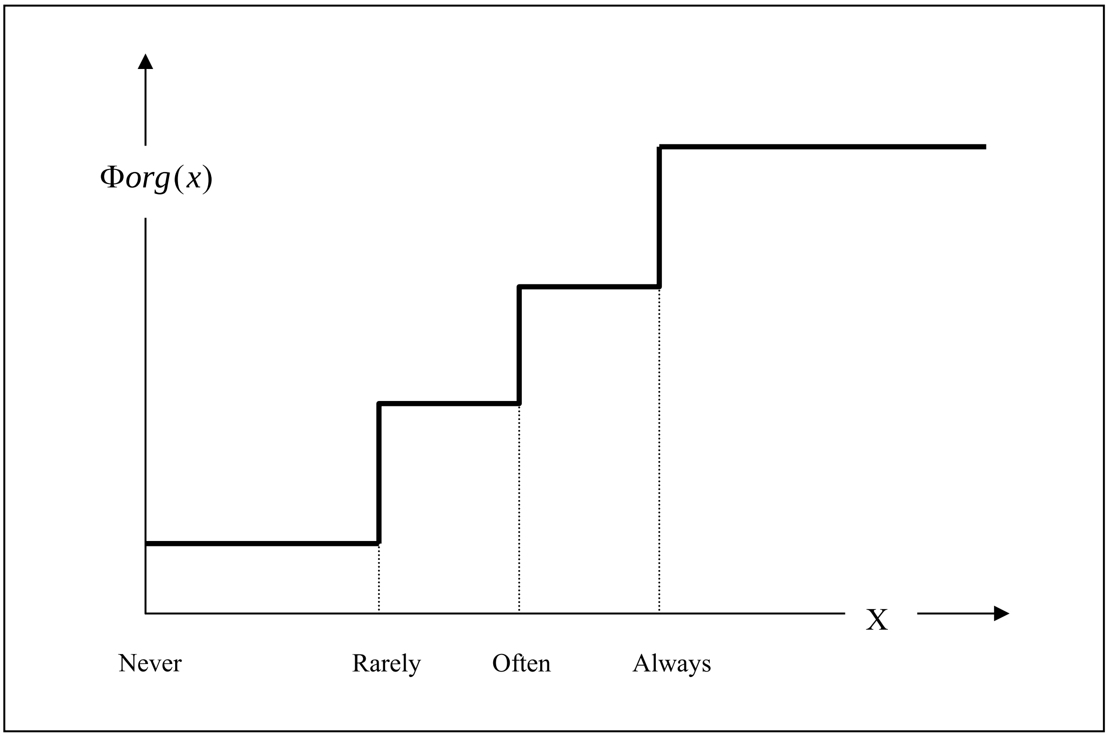

Figure 7. Fuzzy membership function with linguistic values.

More advanced representations of fuzzy membership functions deal with problems where an attribute has more than one related property that depends on each other. Such fuzzy functions are designated as a family of fuzzy membership functions, i.e. an attribute property can belong in various degrees to several related classes at the same time. E.g. a car can, to various degrees, be red, but also contain some degree of blue color.

BN and Multi-Entity BN

Bayesian Networks (BN) is a statistical modelling method used to represent uncertain causal relations between different statistical variables. By using BN methodology it is possible to deal with uncertainty in a uniform and scientifically correct manner. The BN methodology has several potential areas of application within the intelligence domain, e.g. detecting threatening behaviours by insiders, antiterrorism risk management or probabilistic assessment of terrorist threats.

The problem of how to handle complexity arises when we model complex knowledge. In that case the BN becomes very large, with many state variables. When we model knowledge, a clear conception of how the system works is required. As the number of variables grows, the difficulty of envisioning such a model increases enormously [Pfeffer, 1999]. Therefore a process of classifying and describing relations between classes in a flexible manner is required. The concept of Multi-Entity Bayesian networks (MEBN), described in [Laskey, 2004], is a step in that direction. MEBN is based on separate graphical models. Those models are reusable pieces that during the process of situation-specific BN construction produce a sequence of BNs contextual variables. MEBN has the ability to absorb new facts about the world, incorporate them into existing theories, and/or modify theories in light of evidence. MEBN fragments, network entities, specify local dependencies among a collection of related hypotheses. Consequently, they specify joint probability distributions over unbounded and possibly infinite number of hypotheses. These properties lead us to propose MEBN as the key methodology when designing flexible knowledge fragments for NBI.

3 Results

3.1 Knowledge structuring & formalization

In the following section an example of what the DCMF process produces is outlined. Also, the use of the DCMF process, in the context of NBI, is explained. As stated earlier, the purpose of the DCMF process is to produce reusable and generic knowledge components, i.e. Mission Space Models (MSMs). In figure 8 a simplified MSM is shown. This MSM represents the behavior of an aircraft whose mission involves surveillance of an Area of Interest (AOI) and proper actions if a target is identified. The scan and engage activities can be instantiated to reflect the role of a certain aircraft type, e.g. for an attack aircraft type, engage means destruction of the identified targets.

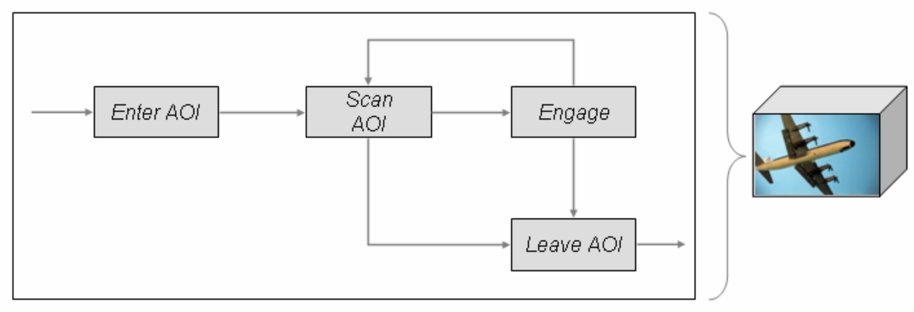

Figure 8. Mission Space Model representing the behavior of an aircraft.

In figure 9, a simple ontology is depicted, which defines airplane classes. The purpose of the ontology is to define concepts and relations in a semantically explicit way for a given target domain. The classes of the ontology are associated with the MSMs. Given that an instance of the J39 class is created, which represents a specific aircraft, this individual is associated with the MSM depicted in figure 8. Thus, the MSM can be seen as rules, applied on information to infer new information or knowledge.

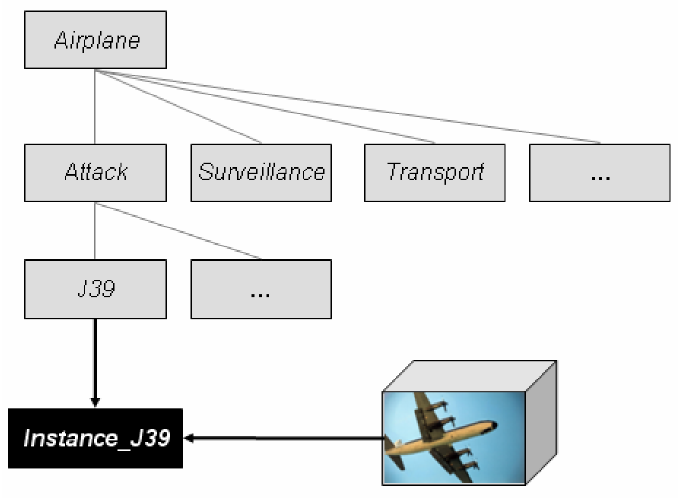

Figure 9. Instance of the J39 class associated with the aircraft MSM.

3.1.1 Required components of the process

Scenario

The idea of the DCMF process is to transform knowledge concerning our world around us to a machine readable and interpretable form. It is required to perform this transformation from some kind of authorized source, e.g. interviews with a subject matter expert. In this study, the first steps of the process are not treated extensively and hence, the knowledge source in this case constitutes a scenario of a military operation. The complete scenario is attached in appendix 1. In figure 10, a brief summary of the scenario is given.

> *The scenario describes a Peace Support Operation (PSO) in former the Yugoslavian Republic of Kosovo. NATO forces are conducting the operation to regain stability and security of the area. A Swedish contingent has been assigned the task to patrol, survey control and escort inhabitants of an Area of Responsibility (AOR). During a routine mission, a Swedish Patrol finds weapons in a forest near the village of Janjevo. The incident is reported back to the Intelligence Division in Stockholm. Further investigation of the case reveals that a certain individual, known for his connections with organized crime in Sweden, is in charge of a military unit that is responsible for a weapons depot which the found weapons originate from. However, some weapons from the depot are still missing. This information raises the suspicion that the weapons are being smuggled to Sweden to be sold at the black market. The Security Division in Stockholm involves the Swedish Customs in the case, and makes some hypothesis concerning possible routes for smuggling the weapons to Sweden. They find a potential suspect in a ship called Pioneer, involved in earlier smuggling activities and anchored near the village of Janjevo. As Pioneer approaches the Swedish coast it is monitored continuously and upon arrival in Gothenburg the ship is boarded by the Swedish Customs. The suspicions are confirmed as the Customs finds the missing weapons hidden on the boat.*

Figure 10. Summary of the scenario used for testing of the DCMF process.

Ontology

As mentioned earlier, the proposed ontology framework of DCMF, which also aligns well with the concept of NBI, includes upper, middle and lower level ontologies. The upper level ontology, chosen for the DCMF process, is SUMO (described in section 2.4.2), whereas the middle level ontology is represented by JC3IEDM (described in section 2.4.2). However, due to time constraint of the project, the upper level ontology has not been used in the tests of the DCMF process, i.e. the upper and middle level ontologies have not been coupled. The ontology representation language chosen for NBI, and the DCMF process, is OWL. Thus, a partial implementation of the JC3IEDM in OWL has been made to serve as middle level ontology in the process. Moreover, a number of extensions (domain ontologies) have been made to the JC3IEDM ontology, to capture domain specific knowledge (in this case the domain of the scenario).

The 5Ws

As a first step in transforming the information and knowledge captured in the scenario to a completely machine readable and interpretable representation, the 5Ws methodology can be applied. The 5Ws stands for *Who*, *What*, *When*, *Where* and *Why* and is a methodology originating from the field of journalism. Apparently, reporters are taught 5Ws as first graders are taught the alphabet. If these five questions are not answered in an article, the story is probably incomplete [5Ws]. In some form of military context these questions answer:

- Who: which unit is to accomplish the task
- What: the task to be accomplished
- When: the timing of the task
- Where: the location for accomplishing the task
- Why: the reason for accomplishing the task

Knowledge Meta Meta Model – KM3

The main purpose of the KM3 is to capture dependencies in and between activities. KM3 provides a specification, which enables creation of generic and reusable conceptual models, and thus, can be seen as a tool for knowledge structuring. The KM3 is activity-centric. In this context, an activity is regarded as an atomic unit of work that is combined with other activities to form processes. For example, consider a process for driving a car from point A to B under varying weather conditions. Depending on the current weather conditions, different sets of activities are employed to build an optimal process, instead of having a range of ready-made processes to manage all possible situations [Andersson et al., 2005].

The KM3 comprises four major components, se figure 11:

1. Model Element
2. Attribute
3. State
4. Rules

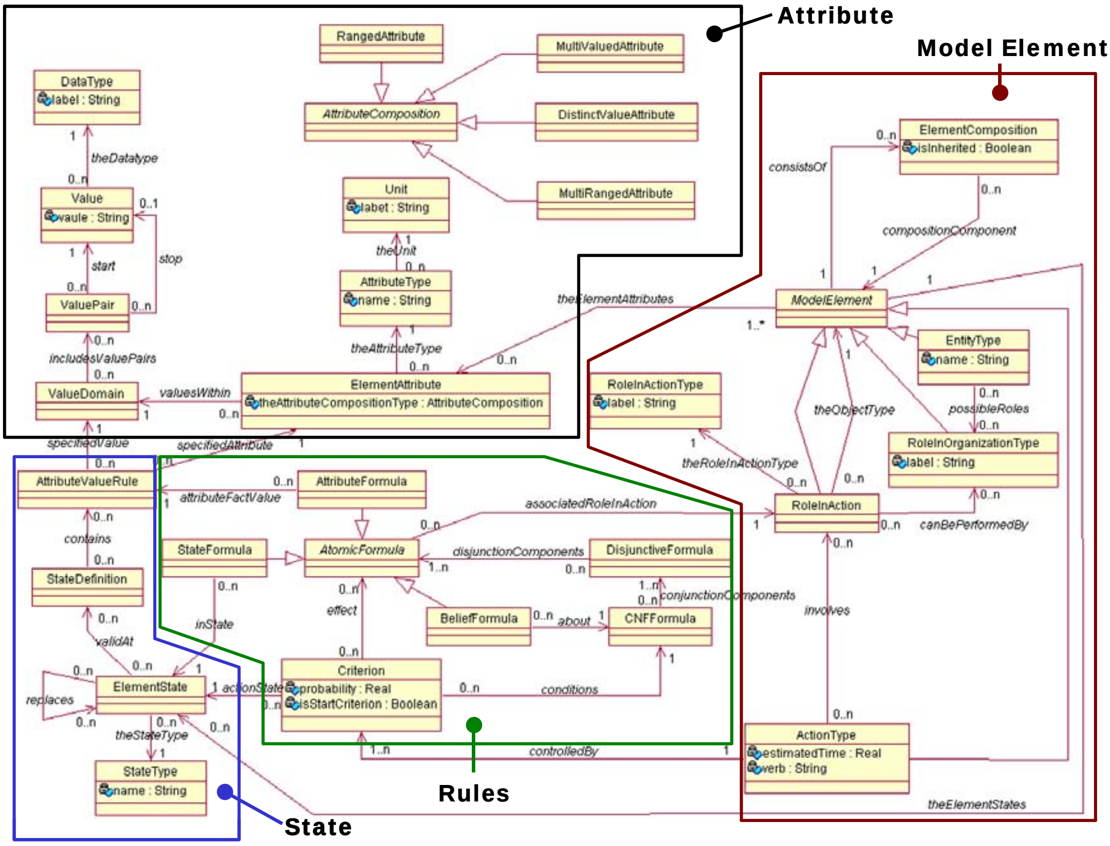

Figure 11. Knowledge Meta Meta Model (KM3) utilized in the DCMF process [Andersson et al., 2005].

The Model Element is the fundamental construct of the KM3 and is used to model objects that are part of activities. In order to describe the characteristics of model elements, attributes are used. An attribute represents a measurable characteristic. A state represents a set of values for non-optional attributes. As these values change the state of a model element is changed. To capture the dynamics of model elements, rules are applied. These describe the conditions under which the activities start and end. An example of capturing knowledge, based on KM3 analysis of the scenario, is given in appendix 2. In [Andersson et al., 2005] a more elaborate description of the KM3 is given.

3.1.2 The DCMF process explained

Below, a brief description of the DCMF process, when applied on the scenario, is made. This description is made from the perspective of NBI, but includes no actual changes of the original process, even though the overall goal of the DCMF project and the NBI project differs. For an elaborate description of the process the reader is referred to [Garcia Lozano et al., 2005] and [Mojtahed et al., 2005].

KA Phase
The DCMF process is initiated when a need for knowledge arises, e.g. an international operation is planned and fundamental knowledge concerning the area of operation needs to be gathered in the form of a knowledge base, e.g. as basis for EBO support. The number one priority in this situation is to find sources of knowledge that are credible. Sources used for extracting knowledge must be authorized and include Subject Matter Experts (SMEs), open and closed sources on the internet, etc. However, before these sources are reviewed, the potential reuse of already existing knowledge in accessible knowledge bases should be evaluated. Reusing knowledge from past operations will of course constitute the most efficient way of assembling the new mission knowledge base. An important aspect of the KA phase is to document the extracted knowledge and to obtain clearance, concerning the interpretation, from the authorized source.

In testing the DCMF process a scenario was chosen to represent the source of knowledge that should undergo structuring and formalization. As described in section 3.1.1, the scenario is about a peace support operation, primarily oriented towards describing an intelligence related series of events. Due to the decision to use this scenario, as the sole knowledge source, the KA phase was superficially treated in the test.

KR Phase
Knowledge does not naturally come in a structured and formalized form. Thus, it has to undergo certain steps to be "readable" and "understandable" from the perspective of a machine. The first step of the KR phase is to structure documented knowledge (in our case the scenario) to a common format, for instance by application of the 5Ws (as explained in section 3.1.1) or the KM3 (as explained in section 3.1.1). When this formatting is completed, the knowledge is mapped to ontologies, providing terms, structures and relations for the target domains, i.e. it is ensured that that the knowledge is expressed using a model that will ensure interoperability with already existing knowledge. At this stage it is important to gain feedback from SMEs, or other accredited persons, to ensure the validity of the formatted knowledge and avoid misconceptions.

In testing the DCMF process the 5Ws and the KM3 were used to provide a preliminary structure of the scenario. The approaches generated two different views of the knowledge contained within the scenario, see appendix 2 for an example from the KM3 analysis. The mapping of the preliminary knowledge structure to the defined ontology, the OWL implementation of JC3IEDM, revealed aspects currently not modeled. In these cases extensions (domain ontologies) to the JC3IEDM were made to make a more complete description of the target domain. For example, constructing a weapons taxonomy to enable representation of the weapons types contained in the scenario.

Table 3 illustrates a subset of the 5Ws analysis, namely paragraph 1 of the scenario in Appendix 1. The corresponding mapping to the JC3IEDM model is shown in figure 12.

Table 3. Example of 5Ws analysis applied on the scenario.

Id	1
Who	Patrol from Swedish contingent KS05
What	Patrolling
When	From 1st May to 31st May
Why	To secure the AOI (Area of Interest)
Where	AOI somewhere in Kosovo

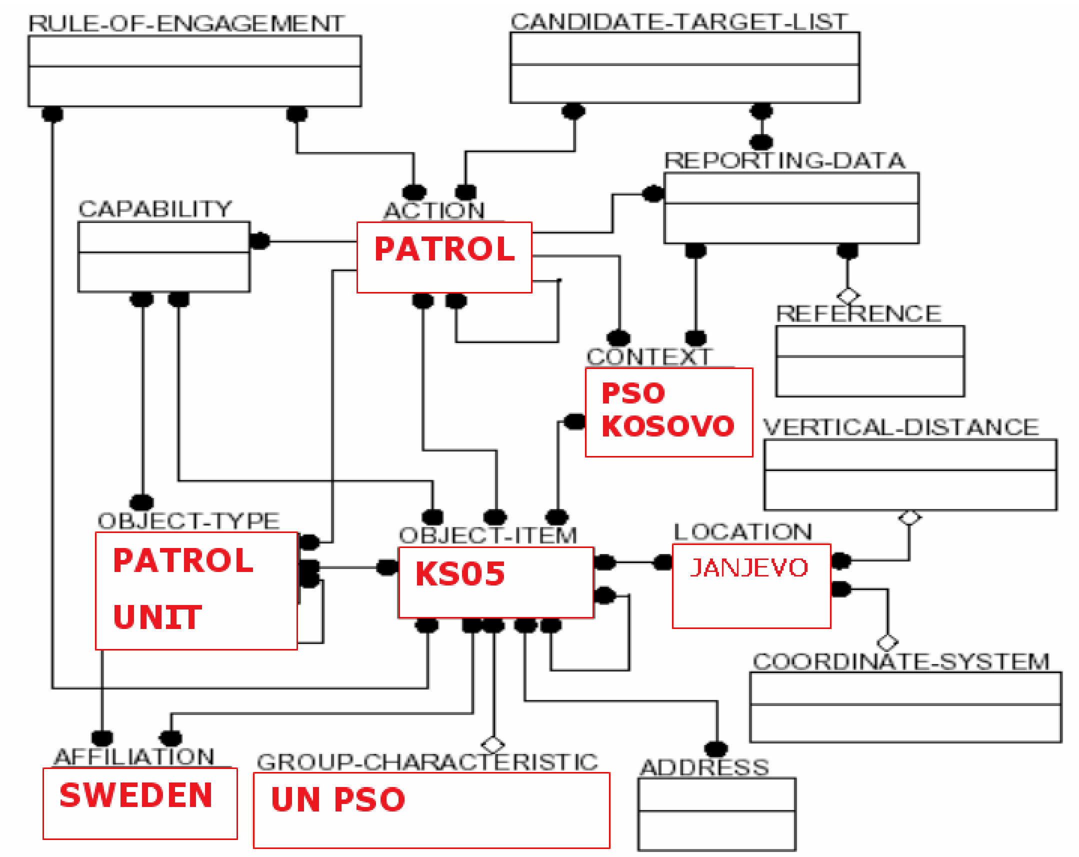

Figure 12. Mapping of structured knowledge to the JC3IEDM.

KM Phase

In the KM phase, the knowledge is modeled by creation of Mission Space Models (MSMs). The modeling relies on the KM3 model, which provides rules and constructs for defining the MSMs. In figure 13, an example MSM is presented expressing captured knowledge from paragraph one of the scenario. The upper part of figure 13 illustrates the generic knowledge captured by the Patrol Mission MSM, whereas the lower part of figure 13 represents the specific case captured in the scenario, i.e. a specific group performs a specific task. The Patrol Mission MSM can be applied to any patrol unit in several contexts, and thus, represents the behavior (rules) of a patrol unit at a generic level. The MSMs in this case, forms the basis upon which inference is performed when instances are created in a knowledge base.

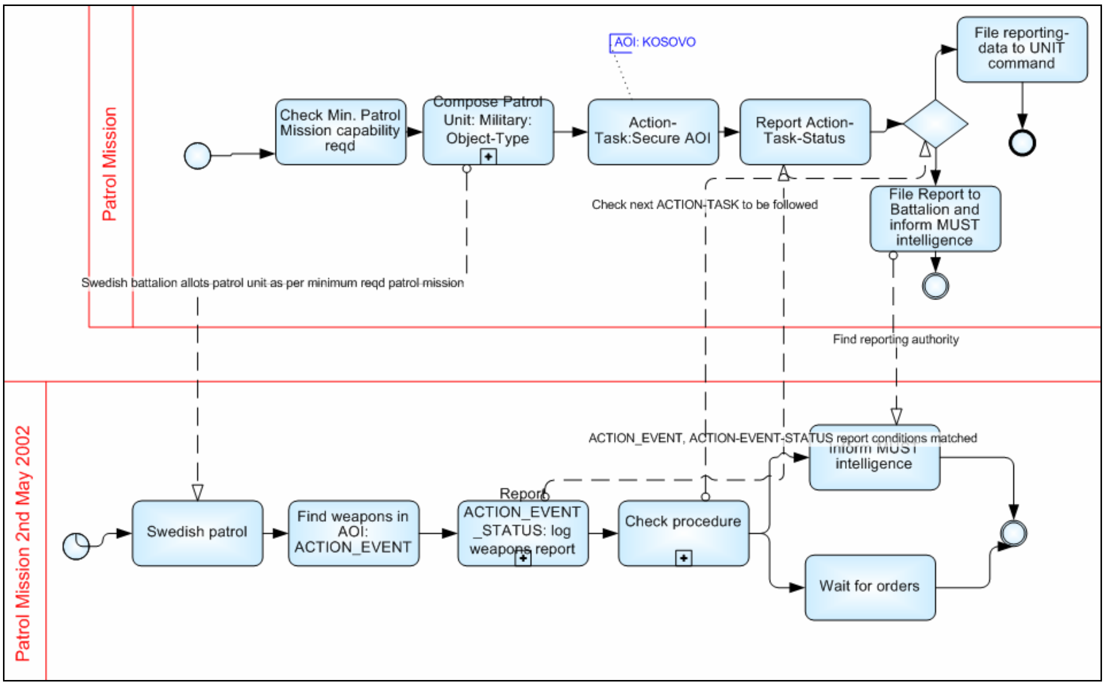

Figure 13. Mission Space Model – MSM.

3.1.3 Experiences from utilization of the DCMF process

For the time being, the DCMF process is not automated. The individual steps of the process require human work. However, the future goal is to develop tools that will automate the process as much as possible. A fully automated process is of course hard to implement, and maybe not even desirable. Thus, it is reasonable to believe that certain steps of the process will be automated, whereas others are semi-automated, i.e. the user is provided support from the machine in some aspects of his work.

In the current version of the KM3, the issue of imprecise or uncertain information is not covered. To enable reasoning in terms of uncertain information, this aspect has to be included in the KM3 in order to satisfy the requirements of NBI. Also, the KM3 in its present form has no formal representation, i.e. it is not represented in a formal language. To enable inference, based on the knowledge (rules) that the MSMs express, this is required. For a more elaborate description of the DCMF process the reader is referred to [Mojtahed et al., 2005].

3.2 Imprecise and uncertain reasoning

The knowledge fragment management process involves assembling of knowledge fragments to gain new knowledge. This process may also involve dissemination towards building new knowledge fragments. Let us assume that we have a number of knowledge fragments, see figure 14. An analyst may want to combine fragments and gain new knowledge. Here, the new knowledge (fragment 7) is simply gained by representing the relation between A and C, based on the relations represented in fragments 5 and 6. The problem of combining knowledge fragments becomes intricate when considering vague ontologies, representing uncertain or imprecise relations.

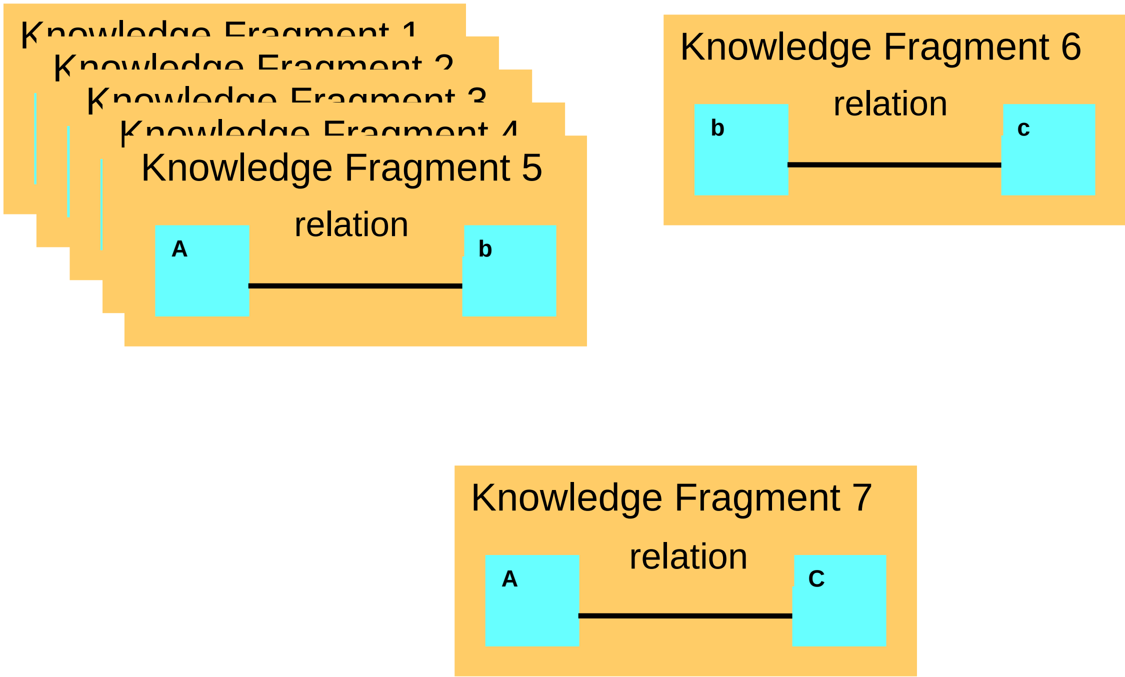

Figure 14. NBI's knowledge management as a process of combining knowledge fragments.

In NBI applications, information is not always certain. We can have multiple-hypotheses about terrorist organizations and different experts may have different opinions. Such knowledge has to be represented in correct and consistent way. Therefore it is crucial, for successful implementation of NBI, to have ontologies that are able to express uncertain and incomplete knowledge.

In this subsection we discuss the need for dealing with uncertainty and imprecision in NBI. Namely, we see two major benefits of using tools that manage uncertainty and imprecision, these are:

- Imprecision in ontology based search, i.e. generation of context dependent knowledge fragments
- Uncertainty and imprecision in problem solving (knowledge fragment management and dissemination to find a solution to a particular problem)

Both issues are still unsolved research challenges. Here we identify and propose some research approaches that involve OWL, BN and Fuzzy set theory.

3.2.1 Dealing with imprecision in ontology based search

An ontology provides the basis for syntactic and semantic metadata tagging. Depending on context, semantic metadata are extracted. We can use an automated classification process to select documents and then classify them as ontological classes. In this manner we can extract data and infer what is relevant to one ore more contexts. However, the tagging and classification is crisp. E.g. a person is either a member of an organization or not.

The tagging of information in fuzzy terms is not a standard in OWL, i.e. we cannot express to which extent a subject and object are related. We simply need a new notation in OWL that introduces an *adverb* that explains the predicate. The representation of adverb should be followed by introducing an appropriate fuzzy reasoner that would operate on an OWL based *fuzzy ontology*. As a result, given a particular context, the user could suppress a number of noisy relations to yield a set of relations of prime importance.

The fuzzy ontology is based on a modification of an existing crisp ontology. Its use is motivated when an ontology comprises a rich set of imprecise relations between entities [Widyantoro et al, 2001], e.g. such as a future NBI ontology. Expressing relations of low importance is not the obstacle in imprecise ontologies. In the query process, relations of importance and summed memberships would be taken into concern. By subtracting relations that do not have a membership degree above a certain threshold, a possible limited number of relations for the current context would be visualized.

Medical document retrieval by [Parry, 2004] is one example where fuzzy ontologies are used. However, automated document classification, generating input for vague ontologies, is still an open research issue [Villa et al., 2004].

The strength of relations, the adverb notion introduced here, can be assigned in one of two ways:

- via a user preference, assigned using a membership function
- automatically (different methods such as laplace estimator etc.)

Here follows a soft retrieval example where fuzzy membership degree is involved. Let the adverb have various degree of strength of relation. Instead of using numbers the user could use words “Opposite”, “Not Related”, “Slightly Related”, “Moderately Related” and “Strongly Related” to describe the strength of relation. The fuzzy membership function would translate the states to the numbers in the fuzzy ontology. Let us take a closer look at figure 15 below. Words that follow the colon sign are names of classes in our ontology.

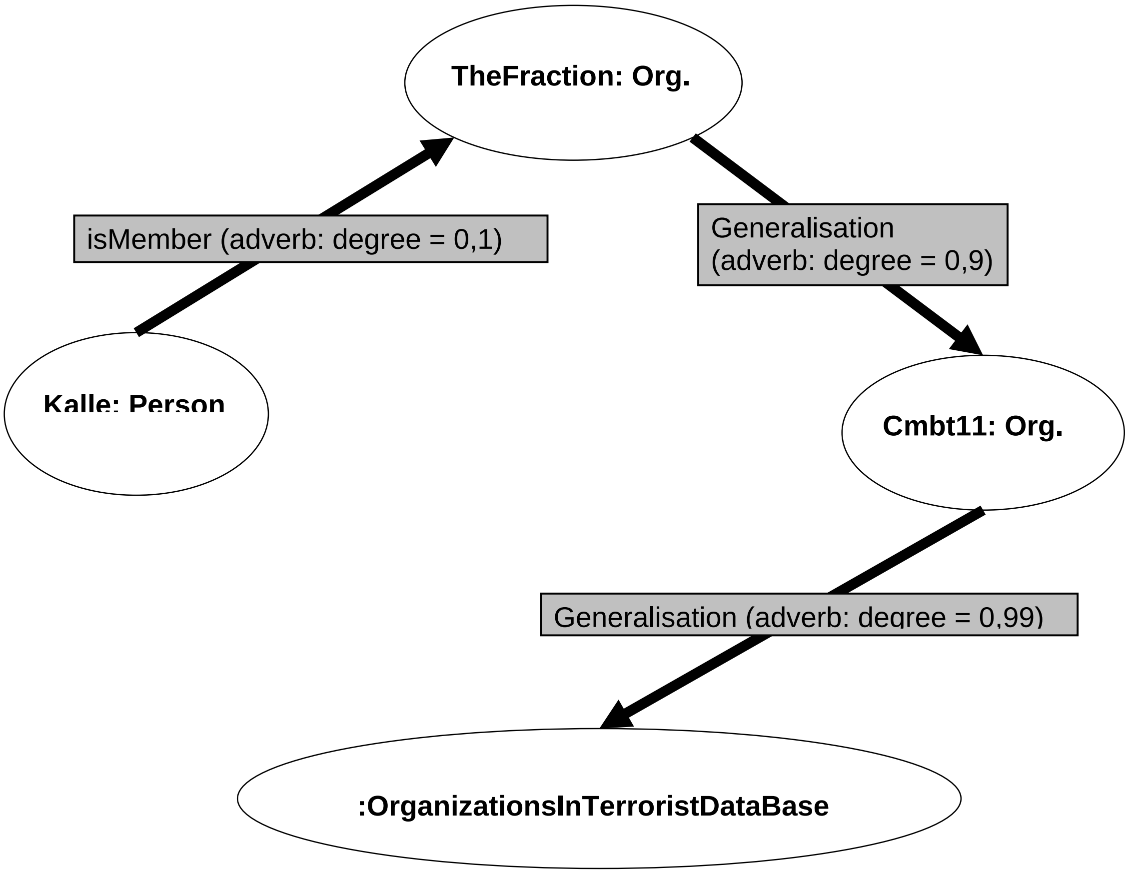

Figure 15. Example of OWL modified notation, introduced here, by using the adverb.

Through representation of a relation's strength, the user can suppress irrelevant relations by specifying a minimum strength of a particular relation. This feature is not possible in a standard OWL based query. Below is an example of a fuzzy ontology query.

Query: :person isMember/:terroristorganisation, (**degree** > **0,3**)

The challenging research issue is how to perform the query using membership degree. The intuitive approach would be finding all relations that fulfill the request whose weakest link is at least above a certain threshold. According to fuzzy set theory this query request would mean finding minimum, *min*(0,1;0,9;0,99) = 0,1 (in figure 15). The interpretation of this statement would be that Kalle is related to terrorist organization by 0,1. Thus, Kalle will not be identified by Query1 since the threshold is set to 0,3. Such information retrieval using fuzzy values and/or probabilities is called *soft information retrieval*.

3.2.2 Dealing with uncertainty and imprecision in problem solving

Recently, a new paradigm called EBO has been introduced, described briefly in section 2.2. "*Beyond simply describing how such (terrorist) groups change for example, tracking* *differences in weapons they use or how well they use them—we need to understand the mechanisms through which those changes occur*", [Jackson et al., 2005]. EBO is a way of thinking and is aimed to support both combat and OOTW (Operations Other Than War). The assumption in EBO is that actions cause results (effects) and mechanisms explain cause. I.e. given that some action(s) are performed the effects may be achieved because of mechanisms. The uncertainty in action, result and cause suggest a probability-based approach (Bayes) [EBO].

EBO analysis emphasizes causal relationships and Bayesian Networks model uncertain causal relationships. The OWL ontology could store knowledge fragments represented as Bayesian network fragments. When solving a particular problem the user should be able to retrieve some of the BN fragments from the OWL database. The process of putting together the fragments could be done by the user, or automated to some extent by using predefined rules. The final BN network could be used for reasoning under uncertainty for solving a particular problem.

3.2.3 Conclusion and recommendation

By using context we put relations together and extract relations relevant to the context. One of the reasons for introducing context is to prune the large number of irrelevant relations in a knowledge base, thus displaying relations in space and time that are of importance for the user. A further improvement can be made by using relations with various strengths (membership degrees). By deselecting relations in a context, under a certain membership threshold, we achieve tractability for the end user, and implication is more rapid, i.e. noisy relations in a context are lowered. Moreover, relations that are noisy in one context can be kept in some other context. By using the approach of fuzzy ontology in OWL, we would gain both a multi-hypothetical way of thinking and a tractable user friendly intelligence support.

Advanced Multimedia Information Systems need the ability to handle both the uncertainty and the imprecision of the representation, access, and retrieval of information. Systems that combine the power of probability theory with the flexibility of fuzzy set theory seem to be building components for a future NBI. However, this will require not only further theoretical work on different formal theories, but also further efforts in the efficient implementation of these theories, see [Boughanen et al., 2003].

4 Discussion

Given a fully functioning process for knowledge structuring and formalization, what type of services can be implemented utilizing an existing knowledge base? In the following sections a number of use cases are described that highlight knowledge utilization in the context of the intelligence enterprise.

4.1 Demonstration of a future NBI-system

Figure 16 illustrates a set of services that an NBI-environment may include. In this case, five main categories of services are outlined; knowledge creation, knowledge association, ontology-based search, EBO-analysis and machine processing. In figure 16 an example is given that illustrate how two users interact with the NBI-environment.

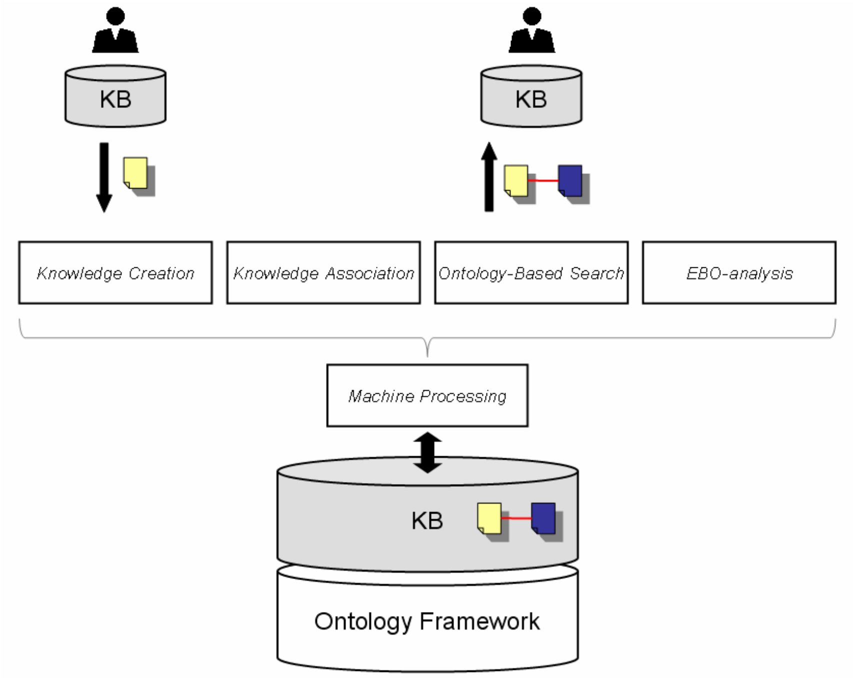

Figure 16. Future NBI-environment.

One of the users utilizes the service for knowledge creation to feed the system with new knowledge. The creation is based on the underlying ontology framework, which makes the new knowledge structured and formalized. As the new knowledge element is entered in the system, the machine processing service interlinks it with an already existing knowledge element automatically (based on a set of pre-defined rules). The second user of the NBI-environment in figure 16 has defined a subscription for the knowledge type created when the two knowledge elements are interlinked. Therefore, this newly gained knowledge is automatically disseminated to the second user. In the following section the main categories of services, as defined in table 4, are presented in greater detail in order to highlight what features a future NBI-environment may bring to the intelligence community.

Table 4. Services of an NBI-environment.

Services	Description
Knowledge Creation	Input of new knowledge to the system, guided by the ontology framework to ensure interoperability
Ontology-Based Search	Extraction of knowledge from the system based on concepts and relations of the ontology framework
Knowledge Association	Association of knowledge elements in a consistent manner to prevent conflicting knowledge and support traceability
Machine Processing	Automatic processing of large datasets to identify patterns and ease processing and analysis of intelligence in general
EBO-Analysis Tools	Analysis of possible chains of events in a system, to identify the most effective measures in achieving desired goals

4.1.1 Knowledge creation

A basic type of service of an NBI-environment would be knowledge creation. This service supports input of new knowledge to the knowledge base of the system. The knowledge creation service must satisfy that the supplied knowledge is structured and formalized according to the models which the underlying ontology framework prescribes. In this case, a fairly simple knowledge creation service is envisioned that is based on forms, and hence, no automatic text mining (Natural Language Processing) techniques are considered at this stage. The forms used for entering new knowledge are based on the models that the ontology framework expresses, see figure 17. For example, the ontology framework might express how a terrorist organization is modeled in a standardized manner, and thus, the user is guided by forms in describing such feature, i.e. what vocabulary to use, what aspects should be covered etc. In this way, interoperability at the syntactic and semantic level is maintained within the system.

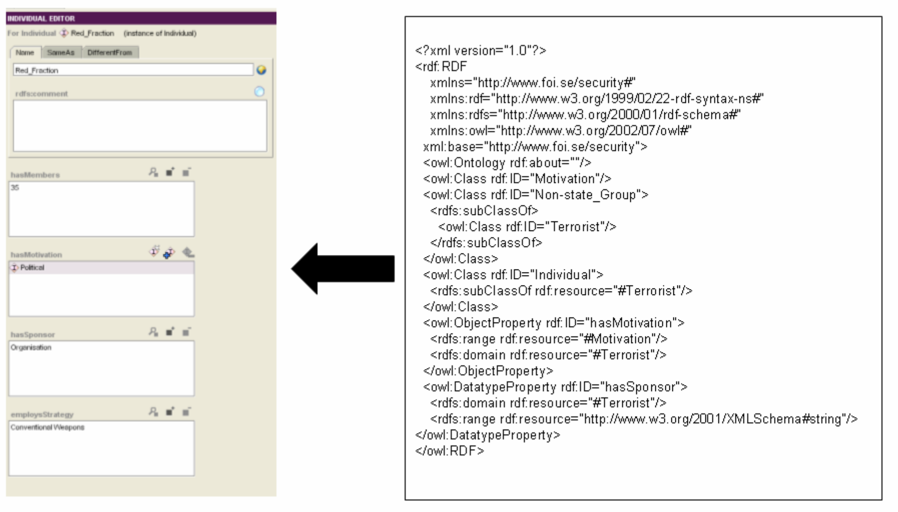

Figure 17. Automatic generation of forms based on the ontology framework.

4.1.2 Ontology-based search

A basic function of the NBI-system is search for information and knowledge. This functionality is provided by the ontology-based search service, which supports refined and precise searches that are not based on keywords. In this context, searches are made based on concepts, and relations between concepts, defined in the ontology framework. The following section describes one typical search that can be employed through use of this particular service, based on [Sheth, 2005].

Figure 18 illustrates a subset of knowledge in the knowledge base of the NBI-environment. This piece of knowledge states that an individual, referred to as beta, belongs to an organization called org. 1, which in turn appears on a watch list. Furthermore, org. 1 owns a server that is administered by an organization called org. 2. The leader of org. 2 is an individual, referred to as gamma, which also appears on the watch list.

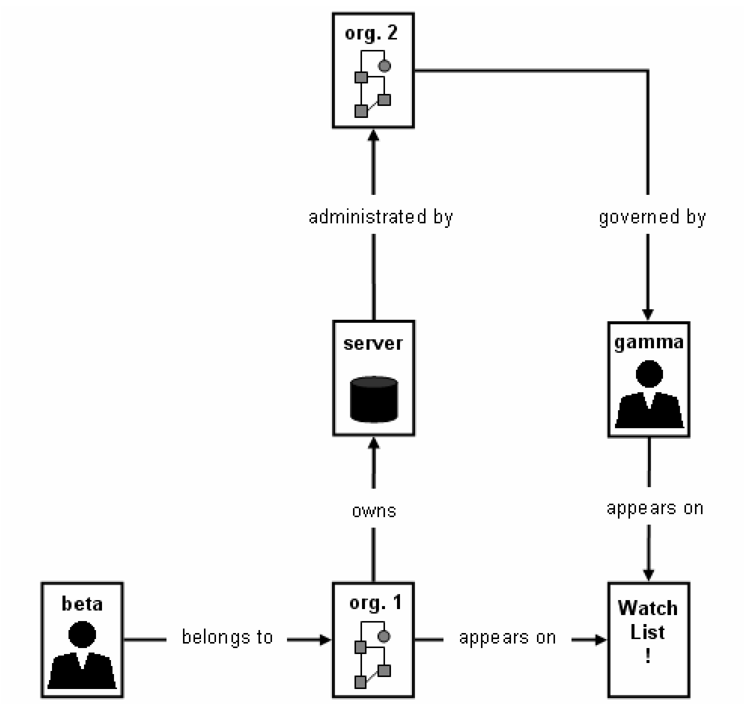

Figure 18. Subset of knowledge in a knowledge base.

Consider the case when some additional knowledge is passed to the knowledge base. This new knowledge states that an individual, referred to as alfa, has received an e-mail that mentions individual beta. Further, this e-mail was sent from the server owned by org.1. The updated knowledge base, comprising both the old a new knowledge, is depicted in figure 19. Given the knowledge in the updated knowledge base, the ontology-based search service can perform a search that finds out if individual alfa has some form of connection with the watch list. A simple way to do this is to analyze semantic association in the network presented in figure 19. For example, all possible paths, connecting alfa with the watch list, can be analyzed to indicate the individual's involvement in subversive activities. From the network in our example the following paths can be identified:

1. alfa – e-mail – beta – org.1 – WatchList
2. alfa – e-mail – server – org.1 – WatchList
3. alfa – e-mail – server – org.2 – gamma – WatchList
4. alfa – e-mail – beta – org.1 – server – org.2 – gamma – WatchList

Based on identified semantic associations an individual can be assigned a threat value, indicating from some perspective how he or she should be handled. Also, this type of search/analysis can be combined with the soft retrieval methodology, presented in section 3.2.1, to suppress noisy relations.

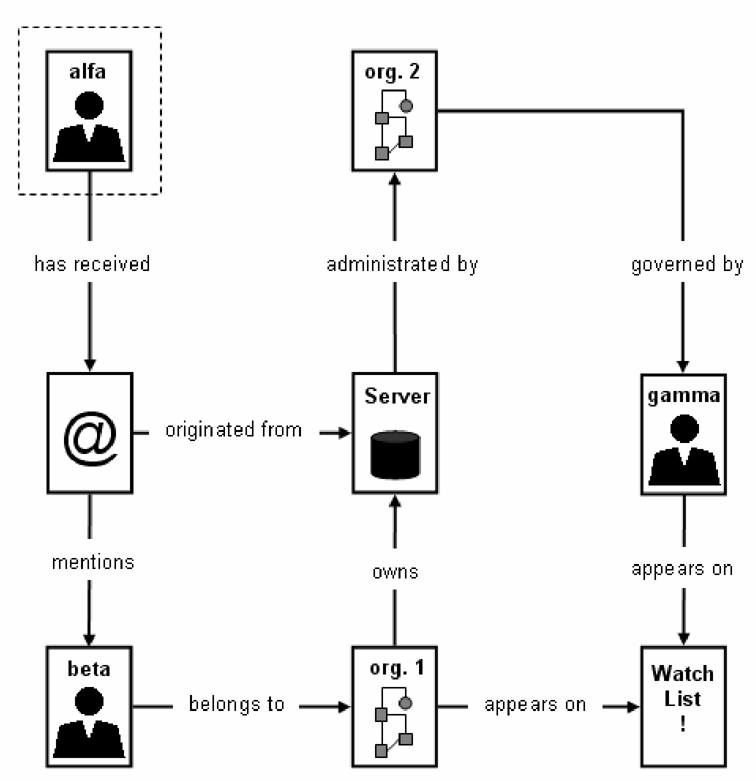

Figure 19. New knowledge is added to the knowledge base.

4.1.3 Knowledge association

An important part of the knowledge creation process is to associate new knowledge with existing knowledge already part of the knowledge base. In the example presented above (ontology-based search) it is required to conclude that the e-mail was sent from the server already represented in the knowledge base. Further, it is required to conclude that the person which the e-mail mentions is individual beta. A fully automated process to accomplish these mappings is most probably highly complex to implement. However, the knowledge association service should guide the user by suggesting possible alternatives in the association process, i.e. it provides semi-automated association of knowledge elements.

Furthermore, the knowledge association service must support management of different temporal aspects of knowledge elements, i.e. when new knowledge replaces, or complements, existing knowledge. In the example presented above (figure 19) the ownership of the server may be transferred from org. 1 to org. 2. In this case it is not desirable to simply update the knowledge structure using the new facts (the ownership transfer). It is also important to preserve the old knowledge structure to enable traceability. The fact that the server was once owned by org. 1, but is now owned by org. 2, may constitute an important piece of information in some context.

4.1.4 Machine processing

If information and knowledge are represented in a machine readable and interpretable way, processing and analysis of intelligence can be done in a more efficient way. The advantage of putting machines to work when processing information and knowledge is obvious; a machine is capable of processing enormous amounts of data at a fast pace, and has the capability to recognize patterns that are hard for a human to comprehend. These patterns can be both spatially and temporally separated.

A process for machine processing of information and knowledge is called inference. Inference is a process through which conclusions are made based on what we already know. Inference has been studied in the AI and logic domains for a long time and has become a cornerstone in the development of the so called Semantic Web. Inference in this context means that rules are applied on knowledge in order to derive new knowledge.

Use of a machine processing service can be illustrated based on the example described above (under ontology-based search). When new knowledge is entered in the system, according to figure 19, the machine processing service can automatically assign a threat value to individual alfa based on a set of rules. Given that the paths between alfa and the watch list are numerous, it is beneficial to let the machine process these and give an estimate of their relevance. This type of processing can be performed for all individuals entered in the knowledge base and serve as basis for further evaluation by a user. Given strong indication of subversive activities, resulting from the inference process, concerned users may be notified automatically.

In this context, it is important to enable inference incorporating uncertainty measures of information and knowledge. In general, conclusions are often drawn when multiple hypotheses have been formulated, based on our fore-knowledge. In the case presented in figure 19 it is not absolutely certain that the individual is involved in subversive activities just because he received the e-mail in question. Thus, it is important to enable management of alternative hypothesis, concerning a particular situation, and an estimate of hypothesis relevancy (probability).

4.1.5 EBO-analysis tools

One of the main driving forces behind the development of the NBI concept was to enable the intelligence community to act in a pro-active manner. One aspect of this ability is to study potential lines of development given a certain type of situation, and to conclude what direct and indirect effects these developments may bring. This type of analysis is central to the concept of Effect-Based Operations (EBO).

A possible application of an EBO-analysis service of the NBI-system would be knowledge element experimentation. If the ability to experiment with knowledge elements, pertaining a certain system of interest, is given to the users, new knowledge and insights may be gained. This could include analysis where knowledge elements are combined in different configurations and where the effects of these configurations are continuously evaluated. As an add-on, this could be combined with simulation techniques to predict possible (predictive) effects, given certain alternative decisions. An example of this type of analysis is given in the following section, based on [Suzic and Wallenius, 2005].

Peaceful demonstrations and protests may degenerate into riots, causing great damage on infrastructure and private property, and potentially even causing loss of human life. In this context, decision makers are often faced with the problem of balancing human rights, as for example the right to free speech, against the responsibility to protect infrastructure etc., i.e. the decision maker faces conflicting goals. By modeling relations, existing among actions, and the influence of actions on direct and indirect effects, a situation may be evaluated from various perspectives and provide support for the decision maker. In figure 20, the result from such analysis is illustrated.

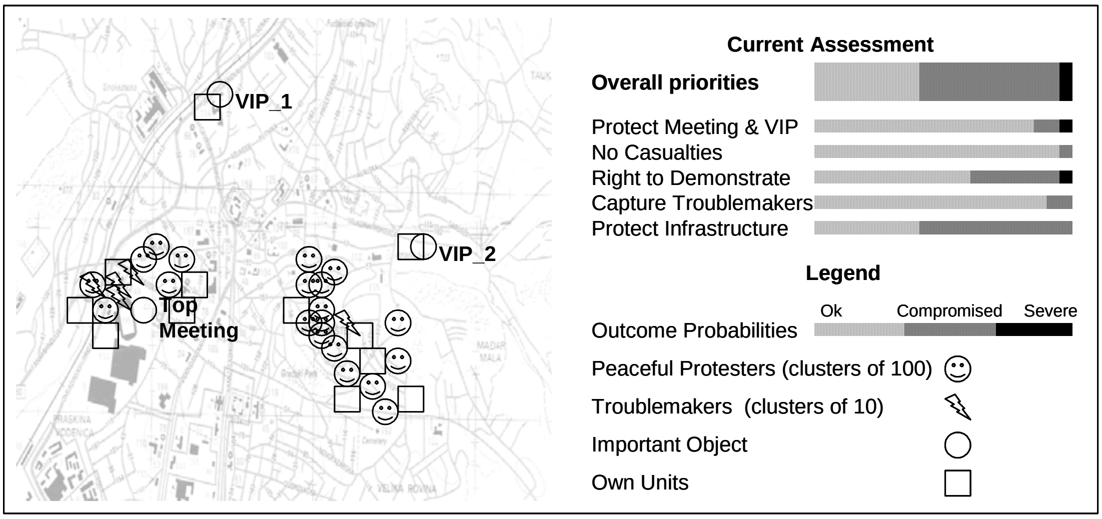

Figure 20. Example of EBO-analysis tool in the context of riot control [Suzic and Wallenius, 2005].

On the left hand side the positions of units of importance are presented, in this case peaceful and aggressive demonstrators and the decision makers own units. Given the objectives of the decision makers own units, the possible outcome of the strategic goals of the current situation are presented on the right hand side. The decision maker has the ability to assign new tasks to units virtually, and in doing so, the probability measures of the strategic goals are reevaluated.

5 Summary & Conclusions

We have explored the possibilities of applying an existing process, the DCMF process, for KBD in the context of NBI. In this work we have applied the DCMF process on an intelligence related scenario, i.e. the process transforms an unstructured text document to a highly structured and formalized form. Further, we have explored the possibilities for representation of uncertainty in formal languages such as the Web Ontology Language (OWL), and the implications of its use within NBI.

For the time being, the DCMF process is not automated. The individual steps of the process require human work. However, the future goal is to develop tools that will automate the process as much as possible. Thus, the work of further developing the DCMF process will continue. From an NBI perspective the process seems to provide tools required for consistent and efficient KBD. Furthermore, an NBI-environment needs the ability to handle both the uncertainty and the imprecision of the representation, access, and retrieval of information. Systems that combine the power of probability theory with the flexibility of fuzzy set theory seem to be building components for a future NBI. However, this will require not only further theoretical work on different formal theories, but also further efforts in the efficient implementation of these theories.

For the next phase of the project we recommend development of an NBI-prototype, demonstrating the potential benefits of a solid ontology framework within the intelligence enterprise. Aspects such as semantic searches, machine processing of extensive knowledge sets, tool support for EBO analysis etc. could be demonstrated by this prototype.

6 References

[Andersson et al., 2005] Andersson, B., M. Garcia Lozano, and V. Mojtahed. 2005. *The Use of a Meta Meta Model (KM3) when Building Conceptual Models of the Mission Space*, Proceedings of the Fall Simulation Interoperability Workshop.

[ATCCIS] Army Tactical Command and Control Information System Working Group, *Overview of the LC2IEDM*, http://www.mip-site.org/ATCCIS/ATCCIS_Baseline_2.htm. Accessed: 2005-09-12.

[Boughanen et al., 2003] Boughanem, M, F. Crestani and G. Pasi. 2003. *Management of Uncertainty and Imprecision in Multimedia Information Systems: Introducing this special* issue, International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 11(1):1-4.

[EBO] Effect Based Operations, www.au.af.mil/au/awc/awcgate/af/ebo.ppt. Accessed: 2005-12-09.

[Eklöf et al., 2004] Eklöf, M., P. Hörling, P. Svan, R. Suzic, and C.H. Yi. 2004. *Information & Knowledge Management for NBI (Network-Based Intelligence)*. FOI-R—1417—SE.

[Garcia Lozano et al., 2005] Garcia Lozano, M., and V. Mojtahed. 2005. *A Process for Developing Conceptual Models of the Mission Space (CMMS) – From Knowledge Acquisition to Knowledge Use*, Proceedings of the Fall Simulation Interoperability Workshop.

[Jackson et al., 2005] Jackson B., J. Baker, K. Cragin, J. Parachini, H. Trujillo, and P Chalk. 2005. *Aptitude for Destruction*, Organizational Learning in Terrorist Groups and its Implications for Combating Terrorism.

[Jensen, 1996] Jensen, F.V. 1996. *An Introduction to Bayesian Networks*, UCL press, London, ISBN: 1-85728-332-5.

[Laskey, 2004] Laskey, K.B. 2004. *MEBN: First-Order Bayesian Logic for Open-World Probabilistic Reasoning,* http://ite.gmu.edu/~klaskey/publications.html. Accessed: 2005-12-09.

[MIP] Multilateral Interoperability Programme, http://www.mip-site.org/. Accessed: 2005-09-12.

[Mojtahed et al., 2005] Mojtahed, V., M. Garcia Lozano, P. Svan, B. Andersson, and V. Kabilan. 2005. *DCMF – Defence Conceptual Modelling Framework*, FOI-R—1754—SE.

[Mojtahed & Garcia Lozano, 2004] Mojtahed, V., and M. Garcia Lozano. 2004. *Kunskapsrepresentation (KR) och Kunskapsmodellering (KM) i CMMS-konceptet*. FOI-R—1433—SE.

[Mulgund et al., 1997] Mulgund, S., G. Rinkus, C. Illgen, and J. Friskie. 1997. *OLIPSA: On-Line Intelligent Processor for Situation Assessment,* Second Annual Symposium and Exhibition on Situational Awareness in the Tactical Air Environment.

[Nichols and Terry, 2003] Nichols, D., and A. Terry. 2003. *Users's Guide to Teknowledge Ontologies*. http://ontology.teknowledge.com/. Accessed: 2005-09-12.

[Niles and Pease, 2001] Niles, I., and A. Pease. 2001. *Towards a Standard Upper Ontology*. Proceedings of the 2nd International Conference on Formal Ontology in Information Systems (FOIS-2001).

[Parry, 2004] Parry, D. 2004. *A Fuzzy Ontology for Medical Document Retrieval*, Proceedings of the Australasian Workshop on Data Mining and Web Intelligence (DMWI2004).

[Pfeffer, 1999] Pfeffer, A.J. 1999. *Probabilistic Reasoning for Complex Systems*, Stanford University.

[Semy et al., 2004] Semy, S., M. Pulvermacher, and L. Obrst. 2004. *Towards the use of an Upper Ontology for U.S. Government and U.S. Military Domains: An Evaluation*. MITRE Technical Report MTR 04B0000063.

[Sheth, 2005] Sheth, A. 2005. *Semantic Association Identification and Knowledge Discovery for National Security Applications*, Journal of Database Management, 16(1):33-53.

[Smets, 1999] Smets, P.1999. *Theories of uncertainty*, http://iridia.ulb.ac.be/~psmets/Uncertainty_HbkFuzzyComput.pdf. Accessed: 2005-09-12.

[Suzic and Wallenius, 2005] Suzic, R., and K. Wallenius. 2005. *Effects Based Decision Support for Riot Control: Employing Influence Diagrams and Embedded Simulation*, To appear in proceedings of Military Communications Conference (MILCOM).

[SUO] Standard Upper Ontology Working Group (SUO WG), http://suo.ieee.org/. Accessed: 2005-09-12.

[SUO-KIF] Standard Upper Ontology Knowledge Interchange Format, http://cvs.sourceforge.net/viewcvs.py/*checkout*/sigmakee/sigma/suo-kif.pdf?rev=1.4. Accessed: 2005-09-12.

[SUMO1] Suggested Upper Merged Ontology, http://suo.ieee.org/SUO/SUMO/index.html. Accessed: 2005-09-12.

[SUMO2] Domain Ontologies, http://www.ontologyportal.org/. Accessed: 2005-09-12.

[Villa et al., 2004] Villa, R., R. Wilson, and F. Crestani. 2004. *Automatically Attaching Web Pages to an Ontology*, Proceedings of International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems.

[Widyantoro et al., 2001] Widyantoro, D.H., and J. Yen. 2001. *A Fuzzy Ontology-based Abstract Search Engine and Its User Studies*, Procedings of the 10th IEEE International Conference on Fuzzy Systems.

[WW] WonderWeb, http://wonderweb.semanticweb.org/. Accessed: 2005-09-12.

[Zadeh, 1965] Zadeh, L. 1965. *Fuzzy sets*, Information and Control, 8:338–353.

[5Ws] Five More Ws for Good Journalism, http://www.inlandpress.org/Main.asp?ArticleID=265&SubSectionID=222. Accessed: 2005-09-12.

Appendix 1 - Scenario

The scene

The scenario is taking place in Kosovo and its surroundings. NATO forces are conducting a Peace Support Operation (PSO) in order to regain stability and security in Kosovo.

Background

The ongoing conflict is an effect of the following course of events:

- War in former Yugoslavia during last decade.
- Diplomatic efforts in 1999 to find a long-term peaceful solution.
- Peace breaks down again
- Interethnic riots in March 2002 on the people of Kosovo
- On 24 March 1999 NATO forces began air operations over the area to prevent a humanitarian catastrophe.

The return of refugees and displaced persons to their original homestead in the Kosovo region during Sep 2001-Mar 2002 went unsuccessfully:

- Returning refugees had no homes
- Riots
- Black market
- Guerrilla operations

Serb military and police forces answered with blockades of humanitarian aids. A number of violations of human rights of ethnic Albanians in Kosovo where reported. The conflict culminated on May 2nd 2002 when Serb forces killed 250 guerrilla men and civilian in an airborne attack.

Planned end-state

The situation of Kosovo, Federal Republic of Yugoslavia is regained to a state of stability and security. Displaced persons and refugees are significantly restored to their original homestead.

The task of KS05

The task of the Swedish contingent is to ensure safety for the inhabitants of the AOR (Area of Responsibility). Albanians inhabit the area mainly, but several thousands of Serbian’s live in the area as well. The duties of the contingent involve escorting people of a particular group through potentially dangerous areas and manning roadblocks in search for weapons and explosives. The battalion also performs patrol and surveillance of the area to mark their presence.

Course of events

Kosovo May 2002

1. A Swedish patrol from the contingent in Kosovo finds weapons in the forest near a village called Janjevo.

2. The observation is reported in the battalion's local Network-based Intelligence system (NBI-system), which triggers encrypted transfer of the observation to subscribers of the concerned information type.

3. The information about the found weapons is made available for Intelligence Division at the Joint Military and Security Directorate (MUST).

4. An officer at MUST receives the information automatically due to the predefined subscriptions for his particular role. The officer creates a main element to be used as point of reference when the errand is explored further.

5. To find more information regarding the case, the officer:
   a. Searches the area near the site where the weapons where discovered using the GIS (Geographic Information System) facilities of the NBI-system. He finds a military weapons depot just north west of Janjevo.
   b. The weapons depot feature in the GIS is interlinked with some supplementary information. This information makes some statements concerning a particular individual, Major Curtan Strangovic, having some relations to the weapons depot. According to the knowledge base of NBI:
   c. Major Strangovic has connections to organized criminal groups in Sweden.
   d. He has lived in Sweden, but moved back to Kosovo in 1995 to support the Serbian struggle.
   e. He is the leader of a military unit that is responsible for the weapons depot in Janjevo.

6. The officer issues an information request, destined for the Swedish contingent in Kosovo, in the NBI system. He wants to know: has the weapons depot been looted? Who or which group could have been involved? The information request is coupled with the main element of the task in the NBI-system.

7. The battalion in Kosovo acquires the requested information and enters the observation in the NBI-system where it is inter-linked with the main element of the task. The supplied information states:
   a. There has been a burglary in the depot and weapons are missing (they know that weapons are missing since they can compare the current state of the depot with an inventory made recently).
   b. People living nearby can tell that there have been some nightly activities in the surroundings of the depot last week.

8. When the supplied information has been disseminated to the officer at MUST, he/she compares weapons missing from the depot with the weapons found in the forest area and establishes that a number of units are still missing. The missing weapons are relatively light and are commonly used by terrorists and other criminals. Heavier weapons like antitank weapons have been left in the forest hiding place.

9. Since Major Strangovic has a connection with Swedish organized criminals the officer estimates that there is a risk that the weapons are destined for transportation to Sweden.

10. All reports and estimates are inter-linked with the main element of the errand and pushed for dissemination at the Security Division

11. An officer at Security Division reads trough the background material from Intelligence Division and also comes to the conclusion that it is reasonable to believe that the weapons might be smuggled to Sweden.

12. Smuggling is not the responsibility of the Swedish Defence. Therefore the errand is pushed for dissemination by the Swedish Customs, having access to parts the NBI-system

13. The customs finds an interesting ship in the port of Budva, situated relatively close to Janjevo, in their knowledge base. The ship, named Pioneer, has earlier been involved in smuggling activities.

14. The officer at the customs estimates that the disappeared weapons could be transported to Sweden with this ship. Since land transportation can not be excluded, the customs raise the readiness at all borders, both at sea and land.

15. The customs requests support from the Swedish Military Defence.

16. The officer at Security Division estimates Pioneers time of arrival to Swedish waters and the ship is being tracked on its way to Sweden, using various external intelligence systems

17. To be able to track the ship in greater detail when it approaches Swedish waters, the Security Division makes an information request through the NBI-system, destined for Sjöbevakningscentralen. Sjöbevakningscentralen is subordinated OPIL.

18. A handling officer at OPIL OPLJ2 receives the request from Security Division and forwards it to Marinens Taktiska Kommando (MTK) which sends a request to Sjöbevakningscentralen in Gothenburg.

19. Sjöbevakningscentralen identifies Pioneer and registers her in the GIS facility of the NBI-system. Then all organizations (OPIL, OPLJ2, MTK, Swedish Customs and the Security Division) can track the ship live on her way into the port of Gothenburg.

20. Upon arrival the customs searches the ship and find the disappeared weapons.

Appendix 2 – KM3 Analysis

Part of the original scenario text:

… An officer at the Intelligence department receives the information automatically due to the predefined subscriptions for his role. The officer creates a main information element to be used as a point of reference when the errand is explored further. To find more information regarding the case, the officer searches the GIS-system with a special interest for the area around village Y. He finds a weapons depot close to it. The information in the GIS concerning the weapons depot is interlinked with additional information. This information concerns a particular individual, Major C. S. He has connections with organized crime in Country X where he has lived. He is the leader of the military unit responsible for the weapons depot. …

Analysis of the text using the KM3:

/ the entity type Intelligence department is a part of the Swedish defence*/*
ET : Intelligence department
ElementComposition :: part of : < Intelligence department, Swedish defence>

/ the entity type NBI is a part of the Information and communications system*/*
ET : NBI
ElementComposition :: part of : <NBI, Information and communication system>
/ the entity type GIS is a part of the NBI*/*
ET : GIS
ElementComposition :: part of : <GIS, NBI>

/ An ActionType related to another action type (occurring After)*/*
AT : Searching *ET* : GIS for additional information
Time : May 2002, AFTER *AT* : Main information element creation
RoleInAction : <searcher, subscriber>
RoleInOrganizationType : <subscriber, *ET* : Subscribing officer>

/ Start and Stop criteria for the action */*
Criterion : (prob 1, isStartCriterion T,
[*ET* : Main information element AND *ET* : relevant information]
ActionState : searching for additional information
Criterion : (prob 1, isStartCriterion F,
[ET : Main information element AND *ET* : relevant additional : T] OR [*ET* : Main information element AND *ET* : relevant additional : F]
ActionState : search for additional information has occurred

/ Effect of the action. A "case file" is updated. Additional EntityTypes with connections are discovered */*
ET : Main information element
State : Updated with additional information

ET : Weapons depot
Attribute : Close to *ET* : Village Y
Attribute : Responsible commander is *ET* : Major C. S.

ET : Major C. S.
Attribute : Connection to organized crime, Organization
Attribute : Lives in Kosovo, Year
StartValue : 1995

StopValue : Now

Attribute : Lived in Country X, Year

StartValue : Before 1995

StopValue : 1995

Attribute : Leader of a military unit responsible for guarding *ET* : Weapons depot, Military unit