INT J COMPUT COMMUN, ISSN 1841-9836
9(1):93-100, February, 2014.

A Practical Military Ontology Construction for the Intelligent Army Tactical Command Information System

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Abstract: The purpose of this research is to construct a military ontology as the core element for implementing the intelligent Army Tactical Command Information System (ATCIS). Using the military ontology, the system can automatically understand and manage the meaning of military information in the system, and hence it can provide a commander with military knowledge for decision making. To construct the military ontology, we define the core concepts of the ontology based on terms extracted from the ATCIS database and complete the ontology by using the mixed ontology building methodology (MOBM). In addition, we implement intelligent ATCIS as a prototype that provides a military concept navigation service and commanders' decision support service to demonstrate how to use the military ontology in practice.
Keywords: military ontology, ontology building methodology, ATCIS.

1 Introduction

To realize network-centered warfare (NCW), Korea developed the Army Tactical Command Information System (ATCIS) as a ground tactics C4I system [1]. The main service domains of ATCIS are the (1) *'information'* domain for reporting battlefield situations such as the state, location, and movement of the enemy, (2) *'operation'* domain for decision making and operational orders based on the battlefield situation, and (3) *'firepower'* domain for analysis of the target and the order of priority for a strike. It is possible to effectively manage the battlefield because the ATCIS domains are organically linked. However, ATCIS provides only the actual facts of the battlefield, and thus the principal decision making, such as "the possibility of hostile provocation" and "the most effective strike method" depends on the intuition and experience of the commanders and staff officers. Commanders and staff officers can make faster and more accurate decisions in urgent battlefield conditions if they have access to specialized military knowledge for battlefield management.

For this reason, battlefield information must be expressed in machine-understandable language using a standardized format; ultimately, the military ontology, which defines various concepts and the meaning of their relationships (semantics), should be built based on battlefield information. In the case of defining rules for developing military knowledge by using the concepts in the military ontology, commanders and staff officers can obtain refined knowledge to help in the decision-making process.

Therefore, this paper has suggested the construction of a military ontology as the first step in implementing intelligent ATCIS. The mixed ontology building methodology (MOBM) [2] was applied for ontology construction, and the kernel ontology was defined based on terms extracted from the ATCIS database. Then the bottom-up approach and the top-down approach were applied to extend the kernel ontology, and finally the military ontology was completed. Also, this paper has described intelligent ATCIS as a prototype that provides military concept navigation service and commanders' decision support service to demonstrate how to use the military ontology in practice. Here, we suggested a method to minimize the time cost when inferring the military rules for decision making by using the query rewriting model.

The rest of the paper is organized as follows. Section 2 provides a review of previous methods used for ontology construction and introduces the outline of the MOBM. Section 3 presents the military ontology constructed by the MOBM and analyzes additional aspects of applying the MOBM to the ATCIS database information. Section 4 describes the intelligent ATCIS, which provides a military concept navigation service and a commanders' decision support service. Finally, in section 5, we draw conclusions and suggest directions for future research.

2 Related works

2.1 Previous ontology building methodology

A significant amount of research has been conducted on the issue of ontology building methodology. The research has employed essentially two approaches. The first collects terminology and builds the ontology by analyzing concepts, forming a hierarchy for the concepts, and defining the relationships between the concepts and the rules for acquiring domain knowledge. Based on the refinement process assigned to this task, the ontology is then completed. Several methods have been reported for accomplishing this task. The bottom-up method starts with the most specific classes and then groups them into more general concepts [3, 4]. The top-down method starts with the definition of the most general concepts and then divides these into detailed sub-concepts [5]. The middle-out method starts with certain middle-level concepts and then applies the bottom-up method or the top-down method as appropriate [6]. The hybrid method merges ontologies developed from the bottom-up method and top-down method into one ontology [7].

The second approach to ontology building involves developing an ontology from database schemas. This work takes three directions: (1) First, extract the entity-relationship (ER) model from the database schema using reengineering, then from that model extract the ontology [8]; (2) given the database schema and ontology, for semantic web applications, extract the mapping rules between them [9]; and (3) generate the ontology structure itself from the relational database schema [10].

The MOBM, a mixed methodology, was proposed based on these works [2]. The MOBM first generates a kernel ontology, which becomes the core, using database information as much as possible and then completes the ontology by applying the bottom-up method and the top-down method to build additional parts of the ontology.

2.2 Mixed ontology building methodology

As mentioned earlier, the MOBM combines the characteristics of both approaches to more effectively represent organizational knowledge on ontology. In the MOBM, mapping rules are defined to extract the main concepts and relationships of a certain domain ontology from the target database schema. This kind of domain ontology is called kernel ontology. Kernel ontology is enhanced by adding upper-level terms and lower-level terms, which are collected from domain knowledge or instances of the target database, because they may contain new concepts or relationships that did not exist in the target database schema. Based on the top-down method, the upper-level terms are conceptualized into upper concepts. In the same way, the lower-level terms are conceptualized into lower concepts using the bottom-up method. Once the upper and lower concepts are developed, they are linked to the kernel ontology. Thus, the MOBM employs eight steps to build domain ontologies, as follows:

- Step 1: Extracting kernel ontology from database schema.

- Step 2: Developing class hierarchies from upper concepts.
- Step 3: Developing class hierarchies from lower concepts.
- Step 4: Connecting these class hierarchies into kernel ontology.
- Step 5: Enhancing the semantics between inter-terms.
- Step 6: Enhancing any restrictions.
- Step 7: Enhancing additional axioms and rules.
- Step 8: Completing the ontology.

3 Practical military ontology construction

3.1 Building scope of military ontology

We adopted the MOBM as an ontology building methodology. In this section, we describe the process of constructing the military ontology from ATCIS according to the MOBM and provide an analysis of what should be considered when the MOBM is applied to ATCIS domains. A military ontology for the core service domains of ATCIS – *information*, *operation*, and *firepower* – has been constructed among various service domains. Currently, we have collected 10,835 related terms from the ATICS database schema and the defense technology information service (DTiMS) thesaurus and electronic drill book, and 6,515 refined terms have been used for the military ontology construction.

3.2 Extraction of kernel ontology

The heart of the MOBM is the utilization of database schema to construct a practical ontology. First, the kernel ontology was built following the mapping rules [2] of the MOBM after extracting the core terms from the database schema. Because the scope of the ATCIS database schema was overly broad, the kernel ontology was created distinguishing the *information*, *operation*, and *firepower* domains. This paper focused only on the *information* domain, and the middle part of Figure 1 shows the hierarchy structure of the concepts in the domain kernel ontology. The MOBM mentions that the hierarchy structure of the concepts is well presented if the hierarchy of the tables in the relational database is properly defined. However, the hierarchy structure of the concepts is not well represented due to scarcity of hierarchies of the tables in the relational database. Therefore, other upper and lower concepts were added to the kernel ontology.

3.3 Creating class hierarchies from upper concepts

Second, the upper concepts of the kernel ontology were conceptualized as a form of class hierarchies. The terms for the upper concepts were mostly collected from the DTiMS thesaurus and electronic drill book and conceptualized into the upper concepts of the kernel ontology by using the top-down approach. Some of the concepts in the kernel ontology did not connect to the upper concepts because they were not conceptualized in the previous step. This step was intended to alleviate this problem by utilizing the concepts defined by domain experts. The upper part of Figure 1 shows the conceptualized upper concepts, and the underlined concepts (e.g., *Tactical_ Operating_ Spot*) are the ones defined by domain experts.

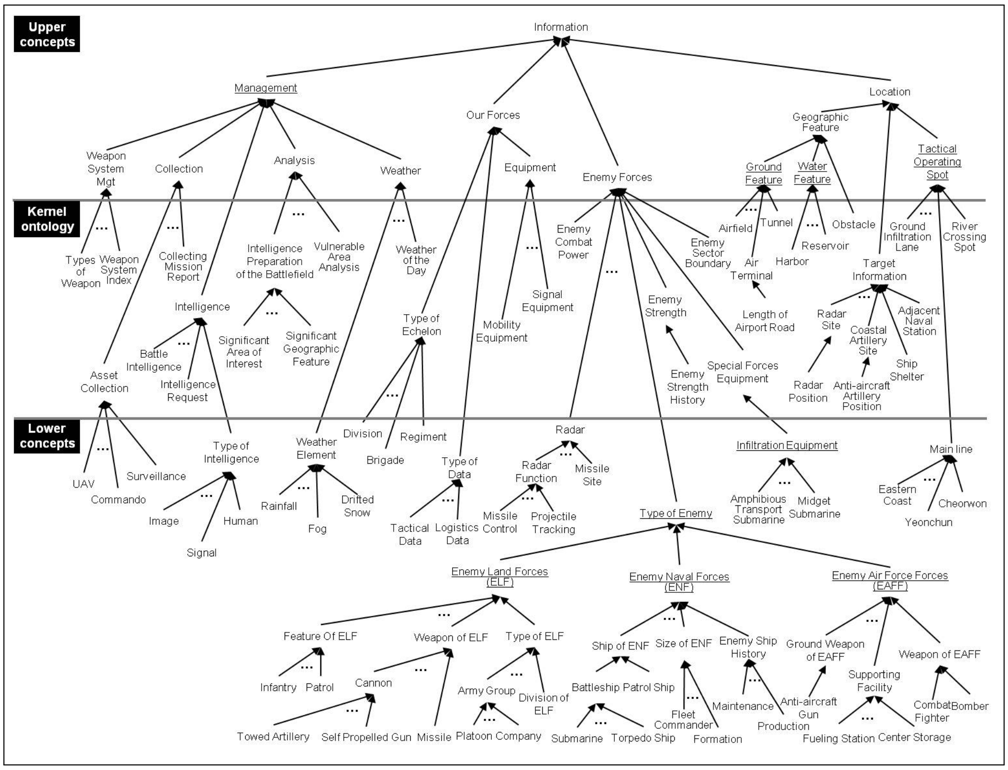

Figure 1: Example of class hierarchy in information domain

3.4 Creating class hierarchies from lower concepts

The third step was to specify the lower concepts of the kernel ontology. The additional information on database instances was utilized in addition to the terms referred to in the previous steps. The instances used in ATCIS can be divided into two types, instances for system implementation and instances for either real-time training or a real situation, and this step focused on specifying the lower concepts based on the instances for system implementation among the two types. As shown in the lower part of Figure 1, the collected terms were conceptualized by following the bottom-up approach, and the intermediate concepts were additionally defined to link the instances with the concepts in the kernel ontology through the MOBM. Here, the code information of the primary key in the ATCIS database directory was used for the intermediate terms, and they were closely related to the hierarchy information by function provided by ATCIS. For example, a user can select *Amphibious Transport Submarine* or *Midget Submarine* as *Infiltration Equipment* among *Special Forces Equipment* from the ATCIS system screen. When referring to this kind of information, *Infiltration_ Equipment* can be used as the intermediate term that links *Special_ Forces_ Equipment* in the kernel ontology to the instances *Amphibious_ Transport_ Submarine* and *Midget_ Submarine.* The fourth step completed the hierarchy of the core concepts in the military ontology by connecting the upper and lower concepts into the kernel ontology, as shown in Figure 1.

3.5 Enhancing the semantics and completing the ontology

The meaning of the military ontology was enhanced through the fifth, sixth, and seventh steps of the MOBM. Following the methods proposed in each step, the *equivalentClass* relationship, *disjointWith* relationship, and *intersectionOf* relationship were defined in addition to the *subClassOf* relationship to reinforce the hierarchy among the concepts. Moreover, the restrictions and axioms were additionally defined, and the domain rules were also proposed after collecting the military knowledge used in commanders' decision making. The final step implemented the enhanced military ontology in Web Ontology Language (OWL) [11] by using Protégé, and the military knowledge was defined as the form of rule by using Semantic Web Rule Language (SWRL) [12, 13].

4 Intelligent ATCIS

To illustrate how military ontology can be used to discover relevant military concepts or provide military knowledge to support commanders' decision making, we implemented intelligent ATCIS as a prototype system. In this section, we describe two services of the system, the *military concept navigation service* and the *commanders' decision support service*.

4.1 Military concept navigation service

To understand the relationship among the various military terms used in intelligent ATCIS, users can employ a Web-based military concept navigation service. As shown in Figure 2, users can enter a keyword (e.g., *Special_Forces_Equipment*) as a query in the upper part of the screen and then click the 'Search' button to start the military concept navigation. The result of the query is displayed in the center of the screen; the classes and individuals are represented as boxes and their corresponding properties are represented as circles connecting the boxes. The starting point for the navigation is the yellow box, which presents the entered query. Users can interactively navigate the underlying military concepts by moving from one box to another. To explore other classes or individuals, users right-click the menu on a selected box (e.g., the *show more* or *show less* function). This navigation process may be repeated until users find the military concepts they seek. This service was implemented in Java Server Pages (JSP) on an Apache Tomcat server and the visualization function related to concept navigation was developed using the GrOWL [14].

4.2 Commanders' decision support service

Commanders and staff officers require decision support services to effectively manage battlefields that are in flux. In particular, in the case of an emergency such as the occurrence of war, the system must provide relevant military knowledge that supports decision making that takes place in a short time. However, existing reasoning engines did not have sufficient inference capabilities for a significant amount of military knowledge. As military knowledge that consists of forms of SWRL rules increases, more reasoning time is necessary to create relevant military knowledge from the military ontology and various military data.

With the intelligent ATCIS, we have developed a commanders' decision support service based on the query rewriting method [15] to resolve the problem. Here, we describe the core function of the service, which is conducted via rewritten SPARQL queries instead of the reasoning engine to create relevant military knowledge in a short time. Figure 3 shows the overall process of the service. For example, when a commander enters queries that include military knowledge, the queries are translated into SPARQL queries. Then, the query rewriting engine divides the SPARQL queries into two parts: the military domain query (MDQ) and the military knowledge-related query (MKQ). In the system, the military knowledge as defined by SWRL is programmed as rule templates. Because the meaning of MKQ depends on military knowledge, the engine refers to military rule (MR) in the rule templates to understand the meaning of the military knowledge. Based on the rules, the triple pattern rewriter can change MKQ into Extended SPARQL Query

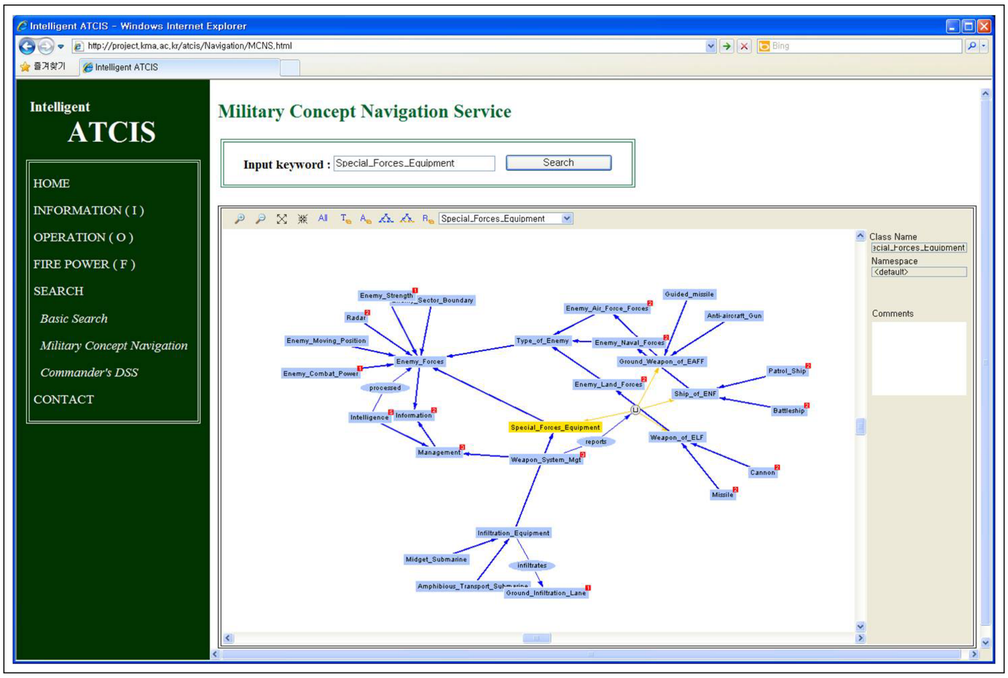

Figure 2: Military concept navigation service

(ESQ). For example, Figure 3 shows that part of MKQ (e.g., *?Troop a MO:Dangerous_ Troop.*) changes in ESQ (e.g., *?Troop MO:hasTowedArtillery ?num . FILTER (?num >= 25).*) according to MR 2, which includes military knowledge (e.g., a dangerous troop is one with more than 25 towed artilleries). Then, the query rewriting engine submits a rewritten SPARQL query to the triple knowledge base and retrieves relevant information from the knowledge base.

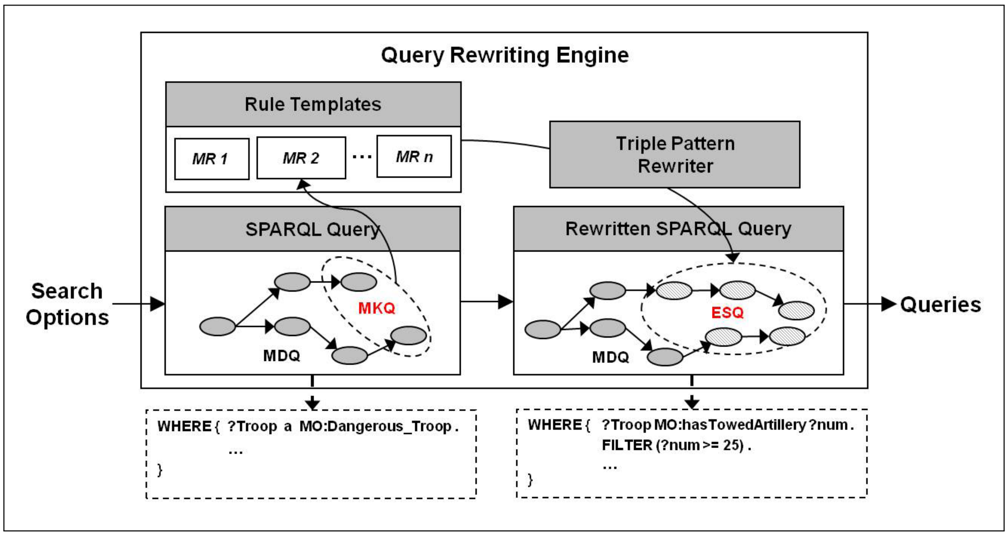

Figure 3: Overall process of the query rewriting method for decision supporting service

5 Conclusion

This paper presented the process of military ontology construction through the MOBM, and considerable additional aspects in each step were analyzed. Using the MOBM, the core concepts of the military ontology were quickly composed from the practical terms in ATCIS, and one can perceive that the more ISA relationships exist in the database, the more effective the kernel ontology constructed. Also, this paper described the implementation of intelligent ATCIS, which provides a military concept navigation service and a commanders' decision support service to show how to use the military ontology. In particular, we proposed a method for minimizing the time cost when inferring the military knowledge through the use of the query rewriting model. The results of this study may be used as the basic material for constructing a more practical military ontology in various military domains.

Finally, future work will be continued in the direction of building the individual ontology, not only for the *information* domain but also for the *operation* and *firepower* domains, and constructing an integrated military ontology by combining the domains.

Acknowledgement

This research was supported by Agency for Defense Development (ADD) under the contract number UD110058MD.

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