A review of military knowledge models

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Abstract. In the process of operation command, the commanders often face a mass of battlefield information information, which mixed with many useless or even false information, This will seriously affect the commander's timely decision-making, and would not meet the requirements of "agile command" for future operations. By constructing military knowledge model, the fault problem of command information system can be eliminated, and finally, the commander will change from "information" to "knowledge". This paper introduces the main contents and related technologies of military knowledge model, and summarizes the development and challenges of military knowledge model.

1. The introduction
With the continuous expansion of the combat space of modern war, the combat forms become more and more complicated, the commanders don't know how to choose when facing the huge amounts of information, the rapid increase in battlefield information does not necessarily mean that commanders have access to more effective information, some invalid information may even interfere with the correct decision of the commander, therefore, the information advantage through knowledge eventually converted to decision-making advantages has become a problem needed to resolve. In 2004, Dr. Paul W. Phister, an expert on aerospace strategic planning at the air force laboratory information board, first proposed the concept of "knowledge-centric warfare" in his paper. Compared to "network-centric warfare", "Knowledge-centric warfare" puts more emphasis on the analysis and judgment of information, in 2006, The US military has officially written "knowledge-centric warfare" into its national defense white paper. It can be seen that the centrality of knowledge is gradually replacing centered on information warfare, the military knowledge model can realize the commander's transformation from "information" to "knowledge" by extracting and integrating massive intelligence information and also can meet the realistic requirement of operational agility advantage in full force.

This paper firstly introduces the research status of knowledge model, and then summarizes the main contents and key technologies of military knowledge model construction. Finally, it summarizes the problems and challenges in military knowledge model construction.

2. Research status of knowledge model
The concept of "knowledge model" was first proposed by Allen Newell[2], The goal of knowledge model construction is to simulate the thinking mode of human beings to make decision reasoning. Knowledge model is the important foundation of knowledge engineering and knowledge system, one of the more influential is the HPKB[3] (high performance knowledge base) project and RKF (rapid knowledge formation) project invested by the defense advanced research projects agency, this program supports the application of combat planning system by constructing military
domain knowledge model and achieved good actual combat results.

High-quality knowledge model can not only improve the work efficiency of the knowledge system, but also improve the knowledge reserve and reasoning ability of the system. Therefore, it is of vital tactical value to construct a complete knowledge model to assist commanders in decision-making. The early knowledge model focused on knowledge representation and the formulation of reasoning rules for problems, and the knowledge base was based on manual construction, so only small scale systems could be developed. To scale up the system, new knowledge modeling methods need to be used to build it. At present, most of the knowledge models are constructed based on ontology and simply classify the knowledge concepts, which makes the knowledge model more discrete in knowledge representation, slower in retrieval speed and less practical. The appearance of knowledge map just makes up for this problem. Knowledge map can intuitively represent the connection between entities. The typical application of knowledge model is various knowledge bases and knowledge systems.

3. Research content of military knowledge model construction

The main research contents of military knowledge model include the following three aspects: one is the construction of military ontology, it can realize the classification, expression, sharing and reuse of military knowledge. The second is to build a military knowledge expert system to provide static battlefield decision-making, which is mainly used in the organizational planning stage of combat missions; The third is to construct a dynamic decision-making model based on bayesian network by using knowledge mapping technology, which is mainly used to express and analyze uncertain and probabilistic events, and to implement dynamic decision-making for operational control and support in the combat phase.

3.1 Construction of military ontology

Ontology theory originated in philosophy, but in computer science its core meaning is a model that describes the relational network of object types, concepts, attributes, and relationship types. Dr Studer of university of karlsruhe in Germany\[^6\]\, defined the concrete content of ontology: "ontology is the explicit formal specification of Shared conceptual model". This explanation has been highly recognized by experts in the field and widely cited by scholars at home and abroad.

As a typical application of artificial intelligence technology in the military field, ontology technology has gradually become a core component of military knowledge modeling. In simple terms, ontology is a set of terms used to describe a field, which constitutes the framework and foundation of knowledge model and is used to manage the pattern layer of military knowledge map.

3.1.1 Military ontology construction method. Ontology construction methods mainly include manual construction, reuse of existing ontology and automatic construction. And at present, domain ontology is mainly rely on manual build, Commonly used manual construction methods such as seven steps, the Metontology method, the method of IDEF - 5, TOVE and skeleton development have been developed more mature, but the manual build method requires a lot of manpower, and low efficiency\[^7\], therefore, how to use the semi-automatic or automatic build method ontology construction became a hot issue of the present study.

The seven-step method developed is often used in the construction of domain ontologies, the main build steps are as follows: one is to determine the area, in the military field, for example, we need to determine the purpose of building before constructing ontology, the second is to investigate the possibility of reusing the existing ontology, the third is to list the important terms in ontology, and the forth is to define the classes and the class hierarchy, these two steps are the core steps of ontology construction and also the most tedious steps, the fifth is to define the attributes of the class and the sixth is to define the surface of the class, lastly, creating an instance of the class, and add the property values.

According to the elements commonly used in combat\[^8\], a reference model of military ontology knowledge is presented in figure 1. By inheriting the concepts and elements of this model, new
concepts can be refined and supplemented.

3.1.2 Ontology language and ontology construction tools. In order to make a formal description of ontology, it needs to be expressed in a prescribed language. In the domain of ontology, representative ontology description languages can be divided into two categories: traditional ontology description language and web-based ontology description language. Traditional ontology description languages include KIF, Cycl, OKBC, etc., which are inadequate in that some concepts and conceptual relationships cannot be accurately expressed by predicate logic. Web-based ontology description languages mainly include XOL, RDFS, SHOE, and OWL.

Currently, the commonly used ontology construction tools are divided into two categories: visual manual construction tool and semi-automatic construction tool. Visual manual construction tools mainly include Protege, Apollo, and OntoEdit, etc. Such tools usually provide users with visual interfaces. Users can complete ontology construction through simple operations. The semi-automatic construction tools mainly include Jena based on Java language.

In a word, there are still many problems in the existing ontology construction tools. Although most of the ontology construction tools have good graphic visualization function and error detection mechanism, they have not yet realized the automatic ontology construction, and still need to spend a lot of manual input and editing, so it is difficult to realize large-scale ontology construction. Therefore, how to use automatic knowledge acquisition to improve the accuracy and efficiency of ontology construction has become a hot research direction to realize automatic ontology construction.

3.2 Military knowledge expert system

In the military field, many problems are not based on the algorithm or function, using the knowledge reasoning method of knowledge map and can not effectively solve the problem. In this case, the experience or knowledge possessed by domain experts can be used to implement problem reasoning by pre-establishing rules, so expert systems are also called knowledge-based systems.

The expert system is mainly composed of knowledge base and reasoning mechanism, and its basic structure is as follows:

![Figure 2. expert system structure](image)

Knowledge base is mainly used to store the domain experts, it contains the rule base and database, the rule base in the expert system can integrate the functions and processes of commanders’ combat
planning and other tasks, and stored a variety of expert theoretical knowledge, common sense knowledge, empirical rules and so on in the form of rules. The database is also called the fact library, which mainly stores the data such as the concept of the problem, the condition of the state and the current problem. As knowledge base is an important theoretical basis for reasoning machine, the representation of knowledge will affect the performance of the whole system. Common knowledge representation methods include production rules, framework method, predicate logic, decision tree, semantic network, etc. In the actual development process, because the production rules are easier to understand, most expert systems are based on the production rules.

Reasoning machine mainly uses knowledge and rules of knowledge base to carry out knowledge reasoning, including forward reasoning, backward reasoning and two-way reasoning. Under a certain strategy or rule, the inference machine can judge which rules in the rule base are helpful to solve the current problem according to the current facts stored in the database, and then create the rule priority table according to the matching degree of the problem, and finally select the rule with the highest priority for problem reasoning.

3.3 Military knowledge map construction and its key technologies

Though, knowledge map and ontology is structured data, but there are differences in meaning, Ontology, as meta-knowledge, reflects common sense or relatively constant knowledge, which has no intelligence value, and usually the knowledge map is the result of information mining, it also reflected that Knowledge maps have the ability to provide fluidity and timing of specific entities and their relationships and events.

The architecture of knowledge map also includes logical architecture and technical architecture, among which the logical architecture of knowledge map can be divided into data layer and pattern layer. The pattern layer is built on the data layer and is the core of the knowledge graph. Ontology technology is used to conceptualize structured knowledge; The data layer consists of a set of facts. Triples such as (entity 1, relationship, entity 2), (entity, attribute, attribute value) are usually used to express facts. Moreover, graph database is used for data storage. Commonly used open source graph databases include Neo4j, Twitter’s FlockDB, sones’ GraphDB, etc.

![Figure 3. Knowledge map construction process](image)

The process of knowledge map construction is also a process of knowledge iteration and update. Each round of update consists of three steps. One is knowledge extraction, which extracts entities, attributes and their relations from the original data source to form a knowledge representation; the second is knowledge fusion, which aims to achieve entity disambiguation and co-reference resolution and reduce the redundancy of knowledge map; The third is knowledge processing. After knowledge fusion, the knowledge with high confidence is selected to be put into the knowledge base, and new knowledge is deduced based on the existing knowledge to realize the iterative updating of knowledge map.

The military knowledge map and the general knowledge map are the same in the construction process and key technologies, but in the specific links need to be refined or specially designed according to the military characteristics. In terms of knowledge extraction, general military knowledge
can be obtained by means of automatic extraction. For structured and unstructured data with confidentiality in the field, automatic and manual extraction can be adopted. In terms of knowledge processing, due to the importance of military knowledge in commanding operations, even a small deviation of data may affect the whole battle. Therefore, it is necessary to add manual verification after quality assessment to ensure the high quality and accuracy of knowledge.

4. Conclusion

It can be seen that commander oriented knowledge model building is also facing many problems and challenges, embodied in the following aspects:

Firstly, rule-based reasoning model cannot achieve accurate reasoning prediction. The existing rule-based reasoning method can only be applied to the auxiliary decision-making of tactical actions in some simple scenarios, and it is difficult to realize reliable decision-making in the battlefield environment with high real-time and high uncertainty, so it is necessary to innovate self-training and constantly evolving intelligent reasoning rules.

The other is the defect of knowledge map itself. In essence, knowledge map can be regarded as a way of knowledge representation, which cannot completely simulate human thinking mode. Therefore, in the face of complex scenario knowledge, human factors may still be needed as the last step of decision-making.

Thirdly, knowledge granularity should be designed rationally. As a domain knowledge model, the knowledge model of tactical commanders often has very specific application scenarios, and the knowledge modeling involves the establishment of entity attributes and inter-entity relationships. However, in the actual operation process, due to the limited data sources of domain knowledge, if the design of knowledge model is too complicated, it may lead to unsupported data and difficult model construction, and affect the retrieval efficiency. If models are built with a coarse-grained body of knowledge, precise reasoning may not be possible. Therefore, in the design process, the knowledge granularity of the model should be designed by taking into account the difficulty of knowledge source and frequency of knowledge application.

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