Design and Implementation of Rule Inference Engine in ESTSWEU

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Abstract. According to the characteristics and requirements of the teaching simulation expert system for weapon equipment utilization, the expert system inference module designs a rule-based reasoning engine technology, the separation of equipment using expert knowledge and control strategy is realized, and the administrator can edit expert knowledge, enhances the expansibility and flexibility of the system. Firstly, this paper introduces the structure, function and equipment rule type of ESTSWEU, and then expounds the general framework and working principle of rule reasoning engine in weapon equipment teaching simulation expert system, and finally the implementation of rules in the rule inference engine framework, the XML-based storage technology, the rule base interface, the equipment database and access interface, the object-oriented rules engine call interface, the rule execution engine processing flow and the establishment of the rule base are introduced in detail.

1. Introduction

With the rapid development of military high-tech, the position of information-based weapons and equipment in modern warfare is becoming more and more important, and new and higher requirements are put forward for the scientific and technological quality of future joint operations commanders and the ability of using weapons and equipment, and then the teaching of using weapons and equipment is also facing new challenges. In the traditional teaching of the use of weapons and equipment, the students' learning of the performance and operation rules of the weapon is through the teacher's explanation and reading related information, the data performance of a large number of weapons and equipment is difficult to understand and remember, students can not fully grasp, the learning effect of students is not obvious. Although teachers have rich knowledge and experience in the use of weapons and equipment, how to effectively impart these knowledge to students in a relatively short time, so that students can fully understand the knowledge and rules of the use of weapons and equipment, and be more flexible and skilled in the use of weapons and equipment, is still challenging [1].

The Expert System for Teaching Simulation of Weapon Equipment Utilization (ESTSWEU) developed by National University of Defense Technology uses advanced technology and means to innovate teaching methods, enhance teaching effect, enable students to master the use of weapons and equipment in a relatively short period of time, and truly realize the transition from classroom to battlefield. This paper mainly studies the core modules in ESTSWEU-the design and implementation of rule inference engine.
2. Estsweu overview

ESTSWEU is a joint operation commander based on operational mission and actual situation of battlefield, based on technical performance and operational capability of weapon and equipment, and guided by operational target characteristics, focus on the overall effectiveness of the weapon system, targeted and overall planning, command, coordination and control activities for operational elements such as operational configuration, operational tasks, operational use and operational operations of weaponry and equipment. The aim is to maximize the operational effectiveness of weapon and equipment system, to achieve the best match with operational tasks, and to enable students to quickly grasp the operational capability of weapon and equipment, so that they can use our weapon and equipment scientifically in future information warfare to fight and win battles.

ESTSWEU system structure adopts the mode of "resource + platform + application". The overall architecture is composed of four levels: infrastructure, simulation resources, simulation services and simulation applications. Its functions include rule reasoning, simulation of weapon equipment application process, visual display, scheme and system evaluation, etc.

ESTSWEU uses rule-based reasoning engine technology to realize reasoning, scheme and system evaluation of weapon equipment use process. The equipment of ESTSWEU is divided into the following categories according to its functions [2]: army equipment, naval equipment, air force equipment, satellite equipment, missile equipment and target characteristics. Each equipment application rule can be abstracted and extracted into the following three types of rules [3]:

1. Single equipment rules, which refer to the use rules of a single equipment or target, include: target matching rules, performance constraints rules, environment matching rules and equipment matching rules. Single equipment rules, which refer to the use rules of a single equipment or target, include: target matching rules, performance constraints rules, environment matching rules and equipment matching rules. Target matching rules: Different combat targets have different characteristics, and how to select appropriate attack weapons according to the characteristics of targets should be considered in the application of equipment. Performance constraints rule: The performance parameters of the equipment reflect the inherent capability of the equipment, and restrict the conditions of the equipment application, including satellite reconnaissance accuracy, aircraft cruise radius, missile strike accuracy, etc. Environmental matching rules: equipment use should consider the limitations of time conditions (satellite overhead time), meteorological conditions, weather conditions and terrain conditions. Equipment Matching Rules: This kind of rules describes the static allocation and coordination relationship between equipment, such as the matching between equipment and ammunition, the coordination relationship between equipment and so on.

2. Combination rules, which can be used to evaluate the multi-equipment usage of a certain type of target in a certain combat mission, describe the basic principles of scheme evaluation and optimization.

3. System application rules, this type of rule is related to the process used by the equipment system, describe the dynamic constraints between equipment from the perspective of system, such as the sequence of application between equipment, the joint use of equipment, etc.

ESTSWEU is under the guidance of certain operational objectives, comprehensive use of our army, sea, air, sky, information and other weapons and equipment, Construction of reconnaissance and surveillance equipment system, information countermeasure equipment system, obstacle blocking and control equipment system, fire blocking and control equipment system, underwater interception equipment system, air surveillance equipment system and surface interception equipment system respectively. Forming a weapon and equipment system with multi-dimensional integration, structural optimization and both offensive and defensive functions to achieve integrated blockade and control effect on targets.

3. General design of rule inference engine

3.1. General framework of rule inference engine

The general framework of rule inference engine includes four parts: rule base, equipment database, rule reasoning engine and rule and database editor.
Figure 1. General framework of rule inference engine.

The database provides facts for the reasoning engine. Rules are stored in the rule base in the form of XML. Rules and facts are input parameters received by the rule engine. The rule reasoning engine includes four parts: object-oriented rule reasoning engine interface, rule execution engine, rule base interface and equipment database interface. Object oriented rule inference engine interface is the interface to provide external program call rule inference engine. The rule base interface and the equipment database interface are used to provide rules engine to access the rule base and equipment library. The pattern matcher decides which rules satisfy the facts or objectives, and assigns different priorities to the rules. Then the rules are added to the agenda. Rule reasoning is responsible for performing specific operations according to the rules output from the agenda. It mainly includes single equipment rule reasoning, combination equipment rule reasoning interface and system equipment rule reasoning. Rules and database editor are used to manage rule base and equipment database. The overall framework of the rule inference engine is shown in Figure 1.

3.2. The principle of rule inference engine

The operation of the rule inference engine is shown in Figure 2.

Figure 2. Principle of rule inference engine.

The external program obtains the information of equipment application scheme input by users, calls the object-oriented rule reasoning engine interface, and transfers the selected parameters to the
specific equipment rule interface. The pattern matching in the rule execution engine obtains the matching rules and the specific attributes of the device from the rule base and the device database respectively according to the incoming parameters. Matching rules are added to the agenda according to a certain priority, and rule reasoning is carried out according to the priority rules in the agenda. Then the reasoning results are stored in the equipment rules interface, and the external program obtains the results through the equipment rules interface.

4. Concrete implementation in the framework of rule inference engine

4.1. The form of rule

By sorting out and extracting rules, we can find out that, the rules of equipment utilization are based on the objectives and the attributes of the equipment and the state of the environment. The rule of equipment extraction is the standardized description of these contents. Using the production rule representation, its general form is:

$$\text{IF } X_1 \text{ AND } X_2 \text{ AND } \ldots \text{ AND } X_n \text{ THEN } Y_1 \text{ OR } Y_2$$

(1)

Production rules are expressed in the form of "condition→ action". Each rule is divided into left and right parts. The left part represents the condition for activating the rule, and the right part represents the action performed after triggering the rule. In the design of the equipment system application rules, in order to simplify the structure of the rules, only a "and" (AND, ∧) connection is used between multiple conditions or multiple conclusions. If there is an "or" (OR, ∨) relationship, it is broken down into multiple rules to represent. For example: $$(X_1 \land X_2) \lor X_3 \rightarrow Y_1 \lor Y_2$$ can be decomposed into the following four conditions and the rules that only contain the "and" relationship:

$$\begin{align*}
(1) & \quad X_1 \land X_2 \rightarrow Y_1 \\
(2) & \quad X_3 \rightarrow Y_1 \\
(3) & \quad X_1 \land X_2 \rightarrow Y_2 \\
(4) & \quad X_3 \rightarrow Y_2
\end{align*}$$

4.2. XML storage technology of rule

XML-based (Extensible Markup Language) is a common way of object-oriented knowledge representation. Because XML has good scalability, self-descriptiveness, and heterogeneity, these excellent features make it the language of choice for distributed knowledge integration.

According to the characteristics of operational application of weapon and equipment, a method of knowledge representation based on XML is proposed. XML file format is used to store rule set, metadata and version information of operational rule base of single equipment system. This storage method is flexible and easy to expand. The rule changes only need to modify the XML file, without modifying the database or code, and the rules in XML format are more suitable for sharing and visiting among different software systems. The following XML technology is used to define a production rule in detail.

```
If  Type and target matching of XX satellites
If  XX satellite available all day
If  The target performance of the XX satellite is 10m
Then  Reasonable results of XX satellite detection of targets
```

Figure 3 shows that <RuleClass>... < RuleClass > represents the specific content of a rule. <RuleID>... </RuleID> indicates that the ID number of the rule is 0001, which is the unique identification rule in the rule base. <RuleName>... </RuleName> indicates that the name of the rule is "R1"; <Priority>... < Priority > shows the priority of rules, 0 indicates that rules do not have priority. <RuleType>... </RuleType> indicates whether the relationship between each If is yes or yes, if it is a number, it means that several Ifs are satisfied to get the result in Then; <If>... </If> is the preceding set of rules, <Pre>... <Pre> represents the elements in the preceding assembly, <Then>... </Then> is the conclusion set. In the preceding set, the relationship between elements is "and", that is, the preceding set can be satisfied only when all elements are established.

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4.3. Rule base interface

The implementation of rule interface mainly uses QFile, QDomDocument, QDomNode, QDomNodeList and other related classes in Qt to implement XML file processing. ESTSWEU's rules mainly include eight stages of equipment and target rules: reconnaissance and surveillance, command and control, information confrontation, mine control, fire control, underwater interception, surface interception and air interception. Because of the different application fields, a rule interface is encapsulated for each stage. The structure of the class is shown in Figure 4. CXML is the base class. The GetDoc() function obtains doc according to the path parameter of the incoming XML file. The FindSection() function finds the corresponding rule nodes for each stage. Each stage class defines four functions: AddNode(), DeleteNode(), AmendNode(), FindNode(), etc. to add, delete, modify, and find operations on the corresponding stage rule types.

![Figure 4. Rule interface class structure.](image)

4.4. Implementation of equipment database and access interface

The equipment database is a database that describes the basic parameters of each equipment, matching targets, matching equipment, and required support guarantees. It includes the equipment information used by the army, sea, air and the Second Artillery Corps. The equipment table design is shown in Figure 5.
This project uses VS2005 as a development platform, using ADO technology in VC++ to achieve access to the database Mysql. The Connection, Command, and Recordset objects are the most commonly used objects in ADO objects; Connection object: used to establish a client connection to the database server and to handle some commands and transactions; Command object: used to process commands passed to the data source; Recordset object: A set of tables used to process data, such as getting modified data.

![Figure 5. Equipment data sheet design.](image)

To facilitate database operations, the above three objects can be encapsulated into two classes, CADODatabase and CADORecordset. The CADODatabase class contains a pointer to the Connection object, and the CADORecordset contains a pointer to the Command object and a pointer to the Recordset object. When calling these two classes, declare two object pointers m_pDatabase and m_pRecordset to add, delete, change, and check the database.

4.5. **Object-oriented rule engine call interface**

The rules engine is a set of dynamic library classes for external program call rule packages, which are included in Inference.dll. Only two classes are required for an external program to call a rule package, one is RuleEngine and the other is RuleEngineFactory. RuleEngineFactory is the factory class that gets the rule engine instance. Usually the code is RuleEngine ruleEngine = RuleEngineFactory.newInstance().getRuleEngine(); after getting the rule engine instance, you can call methods in the rules engine, the main three methods are Put(), Execute() and Get(). Put() is used to pass in the value that needs to be passed in, Execute() is used to run the specified rule package, and Get() is used to get the outgoing value. The general calling code is:

```java
ruleEngine.Put (incoming object);
ruleEngine. Execute ("rule package call name");
Outgoing object = ruleEngine.Get("Outgoing object name");
```

![Figure 6. Object parameter structure.](image)
The passed in object parameter type is QDomNode, the structure of the object parameters is evaluated by the single equipment use, the evaluation of the combined equipment use, and the evaluation of the system equipment use from the inside to the outside. The object structure is shown in Figure 6.

4.6. Rule execution engine processing flow

The rule execution engine is the core of the rule inference engine, which determines the intelligence level of the whole system, and is mainly implemented by the ExecutRule class. The PatternMatch() function retrieves equipment and target information from the database and stores them in the structure variables Equ and Tar according to the parameters in the ObjectParameter object, the corresponding rules are saved to the QDomNodeList type node in priority order. The rule inference function inference() performs single equipment reasoning, combined equipment reasoning and system equipment reasoning one by one according to the priority order of the rules in the SingleAgendaNode, CombinationAgendaNode, and SystemAgendaNode nodes. Write the result to the appropriate location of the object parameter. The ExecutRule class structure is shown in Figure 7.

The rule inference process is shown in Figure 8.

1. According to the task parameters structure, the single equipment rules are added to the single-loading agenda, single equipment rule reasoning for each equipment in each stage of the object parameters, the reasoning result and the reason of the result are written into the evaluation result and the result reason node of the corresponding equipment in each stage of the object parameter.

2. If the number of single equipment in each stage is greater than 1, according to the stage tasks and objectives, acquire the rules of combination equipment to join the combination agenda, and combination reasoning for all the equipment in the stage node, write the combined reasoning result and reason into the stage node combination evaluation result and the combined result reason node.

3. If the number of stages is greater than 1, obtain the corresponding system rules from the rule base according to the acquired phase tasks, and join the system agenda, perform system rule reasoning according to the order of precedence in the rules of the system agenda. Write the result and reason to the object parameter system evaluation result and the system evaluation result reason node.
4.7. Establishment of rule base and equipment library
The main function of rules and equipment library management is to maintain them through the knowledge management interface. Through the management interface, the military expert experience, the operational rules of the warfare and the experience of the exercise, and the new equipment attributes can be added to the library, and the library is continuously updated, improved, and expanded. Weapons and Equipment Operations Management Knowledge Management GUI interactively edits various equipment rules and equipment attributes into the library as a basis for reasoning. The composition of the weapons management knowledge management GUI is shown in Figure 9.

![Figure 9. Weapons and equipment combat operation rules and equipment library management GUI.](image)

5. Conclusion
Aiming at the characteristics and requirements of ESTSWEU, this paper designs a new method of expression representation and storage simplification of mixed forms of object-oriented method, production system and XML technology to improve the effective representation, storage and rapid reasoning of weapon and equipment knowledge. Using XML and Mysql data inventory separately stored rules and weapon equipment entity attributes, rule inference interface for users to make decision-making choices, to achieve separation of expert knowledge and control strategy of equipment use, provide equipment combat knowledge management interface to realize the establishment and editing of expert knowledge by administrators. Through a large number of ESTSWEU teaching practices, the results show that the designed rule inference engine module is fast, accurate and effective, which greatly enhances the scalability and flexibility of the system.

References
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