Research on Equipment Maintenance Support Technology Based on Multi-agent

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Abstract. The maintenance of weapons and equipment currently is mainly regular maintenance. Due to the different running time, working conditions and personnel operation level of each equipment, the uniform maintenance requirements are not scientific. At the same time, the time, place and quantity of equipment failures are lack of effective prediction methods, therefore, the current working state of equipment maintenance is usually called "fire fighting" maintenance. With the increasing number of weapons and equipment, and the increasing complexity of technology, the existing maintenance and support methods have been unable to meet the needs of continuous intact of equipment and rapid troubleshooting. Multi-agent-based equipment maintenance support technology comprehensively considers factors such as mission requirements, equipment distribution, and equipment status, and treat each maintenance resource as an agent. Then use artificial neural network (ANN), reinforcement learning and other intelligent algorithms to realize the overall planning of maintenance and support resources. It can reduce the equipment failure rate and maintenance costs and solve the problem of unreasonable resource allocation.

Keywords. Equipment maintenance, Multi-agent, Intelligent algorithm, Support resource, Resource allocation.

1. Introduction
Domestic equipment maintenance generally adopts the traditional methods of regular maintenance and post maintenance, the user feeds back maintenance information to the maintenance-support center, and the maintenance-support center makes manual deployment decision based on the task situation and maintenance items. As each user's equipment using time, environment and operation level are different, the equipment status is uneven, and the urgency of maintenance needs also becomes different. Current maintenance methods cannot make the prioritize choice of equipment in urgent need of maintenance, thus it may cause losses to users [1-2].

Traditional manual support resource allocation cannot be accurately judged and generally follow "who first wants, who is given first". There will be a shortage of spare parts when more are needed than planned, and the lack of spare parts will largely lead to not solve the equipment problems. Therefore, it is necessary to rationally allocate limited support resources according to the task [3-5].

Multi-agent-based equipment maintenance and support technology is supported by big data of equipment, with the aid of failure mechanism models and intelligent reasoning algorithms to complete equipment failure prediction and health assessment. Through the data platform, the information of equipment maintenance and support needs will be fed back to the equipment maintenance support system. The factors such as task requirements, equipment distribution, and equipment status will be comprehensively considered, and each maintenance support resource will be regarded as an agent.
Neural network algorithm and other artificial intelligence technologies will be used to realize reasonable planning of the support resources [6].

Artificial intelligence and military intelligence technology have been widely used [7]. The research on equipment maintenance and support technology at home and abroad is mainly for the prediction of equipment performance. The common methods for equipment performance prediction mainly include hidden markov model (HMM), artificial neural network model, proportional risk model and state space model. These methods through modeling from different angles and have achieved good prediction results about residual life prediction of the equipment, the residual life prediction can effectively grasp the timely failure information of equipment. The research on equipment performance prediction mainly includes the failure prediction and health management (PHM) technology represented by the United States in abroad. Domestic research on PHM technology started late, but a lot of work has also been carried out and some results have been achieved, such as the high-speed rail PHM system, the Chinese first large passenger aircraft C919 PHM system.

2. Equipment Maintenance Support Platform Based on Multi-agent Technology

To achieve comprehensive consideration of factors such as mission planning, equipment distribution, and equipment status, artificial intelligence technologies, such as reinforcement learning algorithms are used to realize the ability to maintain and adjust resources quickly and plan reasonably. This paper designed the equipment maintenance support platform based on multi-agent technology, which include four subsystems, they are (a) overall structure of equipment data collection and equipment maintenance support platform, (b) equipment performance degradation assessment and fault prediction, (c) single equipment maintenance requirements generated autonomously, (d) intelligent decision of multi-task and multi-equipment maintenance support program. The schematic diagram of equipment intelligent maintenance support technology is shown in figure 1.
2.1. Overall Structure of Equipment Data Collection and Equipment Maintenance Support Platform

Use the existing data collection technology, data standard system application environment construction technology and various business system data integration technologies to achieve equipment construction in the standard system application environment and comprehensive collection of equipment data, providing support for subsequent equipment performance evaluation.

2.2. Equipment Performance Degradation Assessment and Prediction

Using the existing PHM technology and based on equipment operation data, with the help of failure mechanism model and intelligent reasoning algorithm to complete equipment failure prediction and health assessment, then achieved the mapping of equipment operation data to equipment health assessment.

2.3. Single Equipment Maintenance Requirements Generated Autonomous

Using neural network to build the maintenance model which maintenance plan autonomously generated, the input of the neural network are as follows, (a) single equipment health assessment $B_{ij}$ based on PHM, (b) single equipment mission plan $T_{ij}$ (c) single equipment periodic maintenance requirement $D_{ij}$. The output of the neural network for single equipment is maintenance requirement $C_{ij}$.

The rationality of maintenance needs can be measured by establishing a fitness function, the fitness function can be used to measure the rationality of maintenance needs. Combining historical data can
produce a large amount of data for training the neural network. Combining genetic algorithms and neural networks can continuously evolve various parameters of the neural network and finally achieve comprehensive consideration the equipment’s own health, mission plan and regular maintenance requirements, giving reasonable maintenance needs.

2.4. Intelligent Decision of Multi-task and Multi-equipment Maintenance Support Program

Even if the equipment is properly maintained, it will still inevitably fail. When the equipment fails, there will be a need for support (the single equipment support requirement is \( C_{ij} \)). The demand for equipment support requirement \( C_{ij} \) is unpredictable and it is impossible to predict the time, place and quantity of the demand. Combine maintenance requirements \( C_{ij} \) and support requirements \( C_{ij} \), and summarize the requirements of each equipment belonging to the same weapon system to obtain the overall requirements for maintenance and support of each single system.

Requirement for equipment maintenance and support is constantly generated, and resources are constantly flowing. Considering the impact of each allocation decision on the future, facing long-term and overall support benefits, resource allocation can be converted into sequential decision problems, which can be solved using reinforcement learning algorithm. The goal of the resource allocation is to maximize overall returns (not current returns, but long-term cumulative returns).

Consider each resource as an agent, and consider the expected benefit of performing the allocation action \( \alpha \) under the state \( s \), that is the value function \( Q(s, \alpha) \) in reinforcement learning. Consider the fluidity of resources in time and space, the quantify and divide time and space, use historical statistical data to solve the average allocation value function of each time slice in each space, and save the current allocation data to the database to achieve real-time update of historical data. The time and space quantization of a single resource is shown in figure 2.

\[ \sum_{i} \sum_{j} a_{ij} = d \]
\[ \sum_{j} a_{ij} = 1, i = 1,2,3,..., k \]

By setting different weighting coefficients, a value function based on overall consideration can be obtained, and then a resource allocation scheme based on overall consideration can be obtained by using reinforcement learning algorithm.

3. Application of Equipment Maintenance Technology Based on Multi-agent Technology

Research on equipment maintenance support technology based on multi-agents integrates the existing technical means and defines the overall scheme architecture of equipment maintenance support. With the increasing number of equipment deployments and increasing technical complexity, the current
maintenance support methods such as inspection and maintenance of weapons and equipment, on-site support and repair have completed two basic needs, (a) ensure that the equipment is in good condition for a long time; (b) eliminate equipment failure quickly. Equipment intelligent maintenance support technology generates equipment maintenance requirements independently based on equipment operation data. Using reinforcement learning algorithm to rationally allocate resources to maintenance support requirements can effectively improve the current equipment maintenance support level. At the same time, it can improve the ability of equipment to operate in good condition for a long time, speed up the troubleshooting of equipment, and enhance the combat effectiveness of the troops.

4. Conclusion
Implementing equipment maintenance support technology based on multi-agents can solve the problems of reducing equipment failure rates and maintenance costs, and improve the ability of equipment to continue to operate with low failures. It can also solve the problem of unreasonable resource allocation in the past and support the ability of a resource to plan rationally in multi-equipment and multi-task mode. It will effectively improve the level and accuracy of equipment maintenance support, and is of great significance to enhancing the combat effectiveness of the troops.

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